

Does Implicit Memory Extend to Legal and Illegal Nonwords?

Jeffrey S. Bowers

In 4 experiments, implicit and explicit memory for words and nonwords were compared. In Experiments 1–2 memory for words and legal nonwords (e.g., *kers*) was assessed with an identification (implicit) and a recognition (explicit) memory task: Robust priming was obtained for both words and nonwords, and the priming effects dissociated from explicit memory following a levels-of-processing manipulation (Experiment 1) and following a study–test modality shift (Experiment 2). In Experiment 3, priming for legal and illegal nonwords (e.g., *xyks*) was observed on an identification task, and the effects dissociated from explicit memory following a levels-of-processing manipulation. Finally, in Experiment 4, significant inhibitory priming for legal nonwords was observed when a lexical-decision task was used. Results suggest that implicit memory can extend to legal and illegal nonwords. Implications for theories of implicit memory are discussed.

Psychological studies of memory have traditionally relied on tests of recall and recognition. A prominent feature of these tests is that they make explicit reference to past learning episodes and encourage subjects to intentionally retrieve old memories. During the past several years, however, it has been demonstrated that information acquired during a single episode can facilitate performance on a number of tests that do not make explicit reference to a past study episode, such as word-stem completion (e.g., Graf, Mandler, & Haden, 1982), lexical-decision tasks (e.g., Scarborough, Gerard, & Cortese, 1979), and word-identification tasks (e.g., Jacoby & Dallas, 1981), among others. Facilitation in these tasks has been labeled *repetition priming* (Cofer, 1967), and it tends to occur without subjects' deliberate intent to recollect the past episode. Graf and Schacter (1985) used the descriptive terms *explicit memory* and *implicit memory* to describe the forms of memory involved in recall–recognition and priming performance, respectively.

There is now extensive literature in which implicit–explicit memory phenomena for words and objects are compared, and a detailed summary of this literature can be found in several review articles (Richardson-Klavehn & Bjork, 1988; Schacter, 1987; Shimamura, 1986). Three implicit–explicit dissociations are routinely observed in the literature. First, patients with amnesia perform very poorly on explicit tests of memory, but they often perform normally or near normally on a variety of

implicit tests, including the stem-completion task (e.g., Graf & Schacter, 1985; Graf, Squire, & Mandler, 1984) and the word identification task (e.g., Cermak, Talbot, Chandler, & Wolbart, 1985). Second, performance on a variety of implicit tests, including the stem-completion and word-identification tasks, is not generally facilitated by levels-of-processing manipulations (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981; but see Challis & Brodbeck, 1992), whereas performance on explicit tasks is very sensitive to these procedures (Craik & Tulving, 1975). Third, changes in the modality of study–test items reduce or eliminate implicit memory effects (e.g., Graf, Shimamura, & Squire, 1985; Jackson & Morton, 1984; Jacoby & Dallas, 1981). By contrast, these modality manipulations have little effect on explicit task performance (e.g., Roediger & Weldon, 1987).

These results have led to a number of theoretical proposals concerning the underlying basis of implicit memory phenomena. For heuristic purposes, the theories can be divided into two broad categories. In one view, implicit memory is the result of activating or strengthening preexisting memory representations. This framework has been adopted by memory theorists (e.g., Graf & Mandler, 1984; Rozin, 1976), language theorists (e.g., Monsell, 1985, 1987; Morton, 1969, 1979), and some connectionists (e.g., Carpenter & Grossberg, 1987; Murre, 1992); for the sake of expositional clarity, theories propounding this position are labeled *modification* theories. In contrast, it has also been argued that implicit memory is the result of subjects' constructing new memory representations following a single study episode; henceforth, theories propounding this position are labeled *acquisition* theories (e.g., Jacoby, 1983a; Roediger & Blaxton, 1987; Schacter, 1990; Squire, 1987). Although this dichotomy does not capture a number of important distinctions among theories of implicit memory, it nevertheless identifies one dimension on which the theories can be compared. According to modification theories, priming is mediated by processes that act on preexisting memory representations; thus, priming should be restricted to preexisting information. In contrast, acquisition theories propound that priming is the product of new memory representations; thus, priming should extend to novel information. One way to

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Correspondence concerning this article should be addressed to Jeffrey S. Bowers, who is now at the Psychology Department, Rice University, P.O. Box 1892, Houston, Texas 77251.

begin to contrast theories of implicit memory is to determine the extent to which priming effects extend to novel stimuli.

In fact, in an attempt to distinguish between modification and acquisition theories, a number of authors have assessed priming for legal nonwords and line drawings of unfamiliar objects (e.g., Cermak et al., 1985; Diamond & Rozin, 1984; Haist, Musen, & Squire, 1991; Schacter, Cooper, & Delaney, 1990). These materials are not represented in memory as a unit prior to an experimental encounter with them, and consequently, it is commonly assumed that they constitute novel materials that enter memory for the first time during the study episode. Thus, it is argued that the presence or absence of priming for these materials provides evidence in support of acquisition or modification theories, respectively. A detailed summary of the relevant studies can be found in Bowers and Schacter (1993), but an abbreviated summary of the legal nonword results follows.

Priming of Legal Nonwords in Patients With and Without Amnesia

Priming of legal nonwords has been assessed with a variety of implicit tasks, and the results obtained with control subjects have been mixed: In studies in which the lexical-decision task was used, researchers have often failed to observe priming effects for nonwords (e.g., Bentin & Moscovitch, 1988; Forbach, Stanners, & Hochhaus, 1974; Fowler, Napps, & Feldman, 1985), whereas significant effects have generally been obtained with the identification and clarification tasks (e.g., Carr, Brown, & Charalambous, 1989; Feustel, Shiffrin, & Salasoo, 1983; Kirsner & Smith, 1974; Rueckl, 1990; Salasoo, Shiffrin, & Feustel, 1985; Whittlesea & Cantwell, 1987). Fortunately, these conflicting results may have a straightforward explanation. According to Feustel et al. (1983), performance on the lexical-decision task is affected by a response bias that interferes with nonword priming. More specifically, Feustel et al. argued that subjects have a bias to respond "word" whenever they encounter a familiar letter string, and this bias proves to be problematic when subjects encounter nonwords for a second time: Subjects should respond "nonword" to these items, but the familiarity of the repeated nonwords tends to produce "word" responses. The bias thus acts in opposition to the proper "nonword" response, and as a result, priming effects for nonwords are compromised.

If the argument of Feustel et al. (1983) is accepted, and the results obtained with the lexical-decision task are set aside, then priming for nonwords is consistently observed in control subjects (e.g., Feustel et al., 1983; Kirsner & Smith, 1974). Nevertheless, theoretical interpretation of these results with respect to the implicit-explicit memory distinction is not straightforward, because researchers who report significant effects with control subjects have not attempted to dissociate priming from explicit memory. Consequently, it is possible that the observed priming effects were mediated partly or perhaps entirely by explicit memory strategies (see Schacter, Bowers, & Booker, 1989, for a general discussion).

Because the researchers conducting these studies with control subjects did not assess the contribution of episodic memory on implicit test performance, the most relevant

evidence comes from experiments in which researchers have assessed priming for nonwords with patients with amnesia: If robust priming for nonwords were to be observed with these patients, then it would suggest that the findings were not the result of explicit memory strategies. Although in some initial studies researchers failed to obtain significant priming effects in patients with amnesia (Cermak et al., 1985; Diamond & Rozin, 1984), in more recent experiments researchers have reported significant results. Despite these recent claims, however, a close review of the literature suggests that it is premature to conclude that implicit memory extends to legal nonwords.

Cermak, Blackford, O'Connor, and Bleich (1988) reported significant priming for nonwords in S.S., a patient with dense amnesia that is due to the patient having had encephalitis. In this study, patients with Korsakoff's syndrome, S.S., and control subjects studied a series of words and nonwords, and following each list, they were tested on an identification and a recognition task. In the nonword condition, patients with Korsakoff's syndrome, S.S., and control subjects demonstrated 18-, 39-, and 59-ms priming effects, respectively. Their corresponding recognition scores were 63%, 73%, and 86% correct. As Cermak et al. pointed out, these results indicate that S.S. showed priming for nonwords. However, the dissociation between implicit and explicit test performance is not compelling—improved recognition performance was associated with larger priming scores. Consequently, these results may be attributable to explicit memory strategies.

Gordon (1988) claimed to observe significant priming for nonwords in a group of patients with amnesia who were administered a lexical-decision task—a task that often fails to produce nonword priming in control subjects. In this study, patients with amnesia of various etiologies made lexical decisions on words and nonwords, and following 10 to 15 intervening items, the words and nonwords were repeated. With words, patients with amnesia demonstrated a 151-ms priming effect compared with a 122-ms effect with control subjects. With nonwords, however, control subjects showed a 73-ms priming effect and the patients with amnesia showed an insignificant 9-ms effect. Although this result seems to suggest a lack of nonword priming in the patients with amnesia, Gordon reported that the subset of nonwords that was identified especially slowly during the first presentation was identified more quickly during the second display. On the basis of this later observation, Gordon concluded that certain nonwords can be primed in patients with amnesia. By the standard criterion of priming, however, the patients with amnesia failed to show an effect.

Smith and Oscar-Berman (1990) also claimed to observe significant priming effects for nonwords in patients with amnesia. Eight patients with Korsakoff's syndrome completed a lexical-decision task in which words and nonwords were repeated every 15 items on average. Under these conditions, control subjects demonstrated a 59-ms priming effect for words and a 50-ms priming effect for nonwords. In contrast, the subjects with amnesia demonstrated a 131-ms priming effect for words and a nonsignificant -26-ms priming effect for nonwords. Although the patients with amnesia failed to show a priming effect for nonwords when reaction times (RTs) were considered, Smith and Oscar-Berman argued that an analysis of the patients' errors supports the view that priming extends

to nonwords. Whereas control subjects were equally accurate in categorizing items as words and nonwords on the first and second exposures, subjects with amnesia improved by 14.1% for words on the second trial in relation to the first, and their performance for nonwords was 8.9% less accurate for second exposures in relation to first exposures. According to Smith and Oscar-Berman, the increased error rate for the nonwords suggests that the patients with amnesia acquired some information about these items on the first lexical-decision trials, and this information made the lexical decisions more difficult on the second trials. More specifically, Smith and Oscar-Berman argued that the nonwords became more familiar to the subjects as a consequence of the first trial, and this feeling of familiarity biased the patients to respond "word" to the nonwords on the second trial, thus increasing their RTs (cf. Feustel et al., 1983). Although these data can be construed as evidence of nonword priming, it is important to note that the patients with amnesia failed to show priming of nonwords by a standard criterion.

In a briefly described study, Gabrieli and Keane (1988) reported evidence of nonword priming on an identification task with a patient, H. M., with amnesia despite his near-chance level of recognition memory. Haist et al. (1991) also reported significant priming for nonwords in patients with amnesia who completed an identification task. In the Haist et al. study, the exposure time for words and nonwords was calibrated for each subject so that baseline identification performance was 50% for both items. Subjects were then presented with four study-test blocks; they made liking judgments about words and nonwords during the study phase, and then they were administered an identification and recognition task. Under these conditions, the patients with amnesia showed normal priming: Patients with amnesia showed priming effects of .27 for words and .18 for nonwords, whereas the corresponding scores for control subjects were .24 and .20, respectively. In contrast to the similar priming scores that were observed for patients with amnesia and control subjects for both words and nonwords, the performance of patients with amnesia was impaired on a forced-choice recognition task: Patients with amnesia correctly recognized .71 of the words and .74 of the nonwords, whereas control subjects correctly recognized .84 and .87 of the words and nonwords, respectively. It is important to note, however, that the recognition scores of the patients with amnesia were well above chance, which suggests that these patients were only mildly amnesic. It would be interesting to repeat this experiment with patients that are densely amnesic.

Finally, Musen and Squire (1991) reported significant priming for nonwords on a reading task with a group of patients with amnesia. A critical feature of this experiment was that the patients were exposed to the nonwords numerous times during the completion of the reading task, and accordingly, these results may not bear directly on the issue of nonword priming following a single learning episode.

In summary, the literature on legal nonword priming is ambiguous in two respects. First, although nonword priming has been obtained in control subjects, there has been no attempt to dissociate priming from explicit memory. Accordingly, it is not clear whether these priming results should be attributed to implicit or explicit memory processes. Second,

when nonword priming was assessed in patients with amnesia, the results were mixed; there were both positive and negative findings. Given this overall pattern of results, it is difficult to make any strong conclusions regarding the underlying mechanisms that mediate priming for legal nonwords.

The objective of the present experiments is twofold. First, a series of three experiments were carried out to better characterize the memory processes that mediate priming for legal nonwords. To this end, in Experiments 1, 2, and 4 I assessed priming for legal nonwords in control subjects, but unlike in previous studies, these experiments included experimental manipulations intended to test for dissociations between implicit and explicit memory. To the extent that the priming effects dissociate from explicit memory, the results support the view that implicit memory extends to legal nonwords (e.g., Haist et al., 1991). In contrast, if these effects fail to dissociate from explicit memory, then this would suggest that the priming results were mediated by explicit memory strategies. The latter result leaves open the possibility that past reports of nonword priming were mediated by explicit memory strategies as well. The second basic issue concerns the extent to which legal nonwords constitute novel information that can be used to assess the relative merits of modification and acquisition theories. Although the meaning of the phrase *novel information* has often been treated as self-evident in memory research, the matter is complex, and there are reasons to argue that legal nonwords are best characterized in terms of preexisting subword codes (e.g., Seidenberg & McClelland, 1989). Thus, it may be inappropriate to consider legal nonwords as novel information. Instead, it may be more appropriate to consider illegal nonwords as novel information, and consequently, these items may provide a better test for the two theoretical frameworks. Given these considerations, in Experiment 3, I assessed priming for illegal nonwords and, once again, included experimental manipulation intended to test for dissociations between implicit and explicit memory. To the extent that priming extends to illegal nonwords, the results provide strong evidence in favor of acquisition theories of implicit memory.

Experiment 1

As noted earlier, implicit and explicit memory are often differentially effected by levels-of-processing manipulations: As a general rule, performance on recall and recognition tasks is better following phonetic encoding tasks than it is following structural encoding tasks (Craik & Tulving, 1975), and performance on a variety of implicit tasks, including the identification task, is relatively insensitive to levels-of-processing manipulations (e.g., Jacoby & Dallas, 1981).¹ This dissociation has

¹ It is important to note that performance on implicit tasks can be sensitive to levels-of-processing manipulations under some circumstances, for example, when subjects must analyze the semantic content of the target items to accomplish the implicit task (cf. Roediger, 1990). However, in the present experiments, subjects are required to identify the target materials on the basis of perceptual cues, and under these circumstances, performance on priming tasks is relatively insensitive to these encoding manipulations (e.g., Bowers & Schacter, 1990).

been key in developing theories of word priming (e.g., Roediger & Blaxton, 1987; Schacter, 1990), and consequently, it is important to determine whether this dissociation extends to legal nonwords. To address this issue, subjects encoded a list of words and legal nonwords in a structural or phonetic manner, and following a delay, they completed an identification (implicit) task and then a recognition (explicit) task. The critical question is whether nonword priming acts like word priming and dissociates from explicit memory. In addition to manipulating the encoding instructions, three different study-test delays were included in Experiment 1. A number of studies have reported significant nonword priming following short study-test delays and reduced or absent priming at longer intervals (e.g., Bentin & Moscovitch, 1988; Monsell, 1985). It is important to note that these results were obtained with the lexical-decision task, and as noted earlier, there are reasons to avoid this task when assessing nonword priming (cf. Feustel et al., 1983). Nevertheless, the results provide suggestive evidence that word and nonword priming phenomena decay at different rates. Thus, in Experiment 1, I included study-test delays of 0 min, 15 min, and 45 min. The closer the correspondence between word and nonword priming at the various intervals, the stronger the evidence that similar mechanisms mediate priming for both words and legal nonwords.

Method

Subjects. One hundred forty-four University of Arizona undergraduates participated in this experiment for course credit. Forty-eight subjects were tested in each study-test delay condition.

Design and materials. The experiment included one between-subjects and three within-subject variables. The between-subject variable was delay: Subjects completed the identification task following study-test delays of 0 min, 15 min, or 45 min. The within-subject variables included lexicality (words vs. nonwords), encoding task (rhyme vs. structure), and memory test (identification vs. recognition). Consequently, the experiment was a $3 \times 2 \times 2 \times 2$ mixed design.

The experimental materials consisted of 24 legal nonwords and 24 low-frequency words (median frequency = 9 and range = 1–30 occurrences per million) selected from the Kucera and Francis (1967) norms. Words and nonwords were four letters in length and were selected so that no two items shared three letters in the same position (i.e., no two items were orthographic neighbors).

During the study phase of the experiment, subjects studied 12 words and 12 nonwords. The remaining 12 words and 12 nonwords were not studied; I included them on the identification task for use in determining baseline levels of performance and on the recognition task as distractor items. Consequently, the identification and recognition tasks consisted of 48 critical items: 24 studied items (12 words and 12 nonwords) and 24 nonstudied items (12 words and 12 nonwords). Four test forms were created so that each word and nonword could be rotated through both the structural and rhyme study conditions, as well as the nonstudied condition, thus yielding a fully counterbalanced design. In addition, words and nonwords were displayed in a random order during the encoding and recognition tasks. In contrast, items in the identification task were presented in the same order to all subjects, with words and nonwords randomly intermixed. The fixed presentation order was necessary for me to record the subjects' responses.

To observe optimum priming on the identification task, it was necessary for me to determine an exposure duration for words and nonwords that resulted in an identification rate of approximately 50% for nonstudied items. This ensured that floor and ceiling effects would

not obscure repetition effects. In an attempt to determine the appropriate exposure duration for each subject, subjects were presented with an initial identification task that assessed their ability to identify a set of practice words and nonwords. On the basis of their performance on this initial task, subjects were categorized into the slow, medium, or fast version of the experiment. Exposure times for words and nonwords were 45 ms versus 75 ms, 40 ms versus 66.5 ms, and 35 ms versus 58 ms in the slow, medium, and fast conditions, respectively.

Procedure. The experiment was conducted under conditions of incidental encoding: Subjects were told that they were participating in an experiment concerned with word and nonword perception, and no mention of a later memory task was made. Items were presented on a Princeton Ultrasync color monitor controlled by a 386 IBM personal computer (PC) with the DMASTR display software that was developed at Monash University and at the University of Arizona and that synchronized the timing of the display with the video raster. Standard lowercase IBM test font was used. Subjects were tested individually.

In the initial phase of the experiment, subjects completed an identification task that determined the appropriate exposure duration for words and nonwords. The same procedure was used across experiments. In each trial, the target item was preceded and followed by a sequence of four dollar signs (\$\$\$\$) displayed horizontally that acted as forward and backward masks. The forward and backward masks were each displayed for 1 s. Subjects were informed that a series of words and nonwords would be flashed quickly on the computer screen, and they were encouraged to name the first four letters that came to mind after the letters flashed on the computer screen and to respond as quickly as possible. Subjects were allowed to pass if they could not think of any letters, but they were encouraged to respond on every trial. The emphasis on responding quickly and naming the first letters that came to mind was intended to minimize explicit memory strategies that the subject might otherwise adopt during the completion of the implicit memory task (see Bowers & Schacter, 1990, for a discussion of this issue).

In the second phase of the experiment, subjects completed the encoding task. In each study trial, the word *rhyme* or *structure* was presented for 1 s and was followed by a 5-s exposure of a word or nonword. Whenever the word *structure* preceded the study item, subjects were asked to count the number of vowels and enclosed spaces in each item and then to report whether the item contained the same number of vowels and enclosed spaces. (An enclosed space was defined as an area within a letter that could be colored in; for example, the letter *e* has enclosed space, but the letter *m* does not; so the word *maze* has two vowels and two enclosed spaces.) In contrast, when the word *rhyme* appeared, subjects were asked to pronounce the word or nonword out loud and then to generate as many rhymes as possible in 5 s. Ten buffer trials were included in the study session: five primacy buffers at the beginning of the list and five recency buffers at the end.

After a variable delay of 0 min, 15 min, or 45 min, subjects completed the identification task: During the delay period, subjects left the testing room and were not required to complete any distractor tasks. The identification task contained 10 practice items followed by 48 target items: Target items were presented for an exposure duration determined in the first part of this experiment and were preceded and followed by a pattern mask that was displayed for 1 s and was composed of four dollar signs (\$\$\$\$). Finally, subjects completed a recognition task in which items were presented on the computer screen one at a time; subjects pressed the right shift key if they remembered the item from the study list and pressed the left shift key if they did not recognize the item. Items remained on the screen until subjects responded.

Table 1
Percentage of Words and Legal Nonwords Identified as a Function of Delay and Encoding Condition in Experiment 1

Delay	Lexicality			
	Words		Nonwords	
	Rhyme encoding	Structural encoding	Rhyme encoding	Structural encoding
0 min				
Repeat	.65	.69	.70	.63
Nonrepeat	.51	.51	.48	.48
Priming	.14	.18	.22	.15
15 min				
Repeat	.71	.61	.64	.61
Nonrepeat	.55	.55	.50	.50
Priming	.16	.06	.14	.11
45 min				
Repeat	.56	.53	.53	.53
Nonrepeat	.48	.48	.44	.44
Priming	.08	.05	.09	.09
Collapsed over delay				
Repeat	.63	.60	.62	.59
Nonrepeat	.51	.51	.47	.47
Priming	.12	.09	.15	.12

Results

The data are most easily summarized when the priming and recognition scores are collapsed across the delay conditions. When the data are collapsed in this fashion, a strong implicit-explicit dissociation is observed for both words and nonwords. As expected, the subjects' responses to words showed similar priming following the rhyme (.12) and structural (.09) encoding conditions, whereas the subjects' recognition memory was much higher following the rhyme (.42) encoding condition than it was following the structural (.20) encoding condition. The critical finding, however, was that the nonwords showed the same dissociation: Priming was similar following the rhyme (.15) and structural (.12) encoding conditions, whereas recognition memory was much higher following the rhyme (.44) encoding condition than it was following the structural (.22) encoding condition.

Identification. The identification results in the various experimental and control conditions are displayed in Table 1. Four aspects of the identification data are noteworthy. First, significant priming was observed in 10 of the 12 experimental conditions (smallest significant value: $t(47) = 2.13$, $p < .05$, $SE_M < 3.51$). The only insignificant priming effects were obtained for words in the structural encoding condition following delays of 15 min and 45 min (largest value: $t(47) = 1.49$, $p > .05$, $SE_M < 3.56$). The reduced priming effects for words must be considered somewhat anomalous, because numerous studies have obtained significant priming effects under similar experimental conditions (e.g., Jacoby & Dallas, 1981). Second, similar priming effects were observed for words and nonwords. When the data were collapsed over the encoding conditions and delay, word and nonword priming effects were .11 and .14, respectively. Third, similar priming was obtained in the structural and rhyme encoding conditions. When the data were collapsed over the delay condition, priming for words was .12 and .09 in the rhyme and structural encoding conditions, and

nonword priming was .15 and .12 in the corresponding conditions. As noted in the introduction, this result has been reported numerous times for words (e.g., Jacoby & Dallas, 1981), but this is the first report that priming for nonwords is relatively insensitive to a levels-of-processing manipulation. Fourth, priming was reduced in the longer study-test delay conditions. When the data were collapsed over the lexicality and encoding conditions, priming was .17, .12, and .08 in the 0-min, 15-min, and 45-min delay conditions, respectively.

An analysis of variance (ANOVA) confirmed this description of the results. A significant effect of delay was observed, $F(2, 132) = 4.94$, $p < .01$, $MS_e = 873.95$, as well as a three-way interaction of Lexicality $\times$ Encoding Task $\times$ Delay, $F(2, 132) = 3.53$, $p < .05$, $MS_e = 36,901.99$. This interaction reflects the fact that priming was selectively reduced for words after structural encoding in the long delay conditions. As mentioned earlier, the lack of word priming following the structural encoding instructions is considered anomalous. The effect of lexicality, $F(1, 132) = 1.87$, $p > .17$, $MS_e = 695.33$, was not significant, and the effect of encoding task, $F(1, 132) = 3.66$, $p = .06$, $MS_e = 354.97$, only approached significance. These latter analyses support the claim that similar priming was obtained for words and nonwords following the structural and rhyme encoding conditions.

Recognition. The recognition memory results in the various experimental and control conditions are presented in Table 2. For purposes of statistical analysis, hits minus false alarms were subjected to an ANOVA. Three aspects of the data are noteworthy. First, similar recognition scores were obtained for the words and nonwords. When collapsed over the delay and the encoding task variables, subjects scored .31 and .33 for words and nonwords, respectively. The finding that words and nonwords were remembered equally well may seem surprising given the general finding that meaningful materials are better remembered than meaningless materials (e.g., Underwood, 1964). A critical feature of the study procedure, however, was

Table 2
Percentage of Words and Legal Nonwords Recognized as a Function of Delay and Encoding Condition in Experiment 1

Delay	Lexicality			
	Words		Nonwords	
	Rhyme encoding	Structural encoding	Rhyme encoding	Structural encoding
0 min				
Hits	.78	.53	.77	.55
False alarms	.33	.33	.27	.27
Hits - False alarms	.45	.20	.50	.28
15 min				
Hits	.75	.58	.73	.52
False alarms	.37	.37	.29	.29
Hits - False alarms	.38	.21	.44	.23
45 min				
Hits	.76	.53	.69	.49
False alarms	.33	.33	.30	.30
Hits - False alarms	.43	.20	.39	.19
Collapsed over delay				
Hits	.76	.54	.73	.51
False alarms	.34	.34	.29	.29
Hits - False alarms	.42	.20	.44	.22

that subjects were required to make structural and rhyme judgments. If semantic study procedures had been used, then it is possible that recognition memory would have been superior for words. Also, there was a large effect of the encoding task variable. When collapsed over delay, subjects scored .42 and .20 for words, and .44 and .22 for nonwords, in the rhyme and structural encoding conditions, respectively. Recognition memory also seems to be relatively insensitive to the delay variable. When collapsed over the encoding task and lexicality variables, subjects scored .36, .32, and .30 in the 0-min, 15-min, and 45-min delay conditions, respectively.

An ANOVA confirmed this description of the results. A significant effect of encoding task indicated that the levels-of-processing manipulation improved recognition memory more in the rhyme than in the structural encoding condition, $F(2, 132) = 133.99, p < .01, MS_e = 511.25$. The remaining effects did not approach significance.

The preceding analyses indicated that although performance on the identification task was not influenced by the levels-of-processing manipulation, recognition memory was strongly affected by this variable. In addition, the analyses revealed that priming was reduced by delay manipulation, whereas recognition memory was not significantly reduced. To compare recognition and identification performance more directly, I carried out an overall ANOVA that included memory test as a within-subject variable. Not surprisingly, the analysis revealed the Memory Test $\times$ Encoding Task interaction to be highly significant, $F(1, 132) = 65.00, p < .01, MS_e = 391.79$. This result is consistent with numerous studies that have reported a dissociation between implicit and explicit memory following a levels-of-processing manipulation. The critical extension of the present study, however, is that the same interaction was obtained for both words and nonwords, as indicated by the fact that the Memory Test $\times$ Encoding Task $\times$ Lexicality interaction did not approach significance, $F(1, 132) < 1$. In contrast to the Memory Test $\times$ Encoding Task interaction, the interaction of Memory Test $\times$ Delay did not approach significance, $F(2, 132) < 1$, although an overall effect of delay was obtained, $F(1, 132) = 3.66, p < .05, MS_e = 1,239.95$. This finding indicates that the overall rate of forgetting for words and nonwords did not differ in the two tasks. Finally, a four-way interaction of Lexicality $\times$ Encoding Task $\times$ Memory Test $\times$ Delay reached significance, $F(2, 132) = 3.57, p < .05, MS_e = 258.01$. This interaction reflects the fact that priming of words following the structural encoding condition was greatly reduced at the longer delays. As noted earlier, the lack of priming for words under these conditions is considered anomalous.

In addition, three separate ANOVAs that included lexicality, encoding task, and memory test as within-subject factors were carried out at each delay condition. A significant Test $\times$ Encoding Task interaction was observed at each delay, all $F(1, 44) > 13.10, p < .01, MS_e < 501.87$. Accordingly, the implicit-explicit dissociations were reliable at the 0-min, 15-min, and 45-min study-test delay conditions.

Discussion

Consistent with past research, in Experiment 1 there was robust priming for nonwords when an identification task was

used (e.g., Feustel et al., 1983). The critical new finding, however, is that nonword priming dissociated from explicit memory following a levels-of-processing manipulation. The priming effects obtained with words were somewhat anomalous in that the items failed to show significant priming at long delays following the structural encoding task. In contrast, significant nonword priming was observed at all study-test delays, and critically, the effects dissociated from explicit memory at each delay interval. Consequently, the results of Experiment 1 provide evidence that priming for words and nonwords is similar in two important respects; namely, both sets of materials were relatively insensitive to level-of-processing manipulations and showed similar priming at the various study-test delays, at least in the rhyme encoding condition. Thus, the results provide preliminary evidence that implicit memory extends to legal nonwords.

These results are difficult to reconcile within a modification framework that assumes that priming is the result of activating or strengthening preexisting memory representations. As noted earlier, this view assumes that implicit memory only extends to materials that are encoded in memory before the experimental session. As long as it is assumed that legal nonwords do not possess preexisting memory representations, the significant nonword priming results pose a challenge to this approach.

To accommodate previous reports of nonword priming within the modification framework, Monsell (1985) suggested that although priming for words is mediated by preexisting representations, priming for nonwords is mediated by episodic memory processes. On this account, word and nonword priming effects are mediated by fundamentally different mechanisms, thus priming results obtained with nonwords do not compromise a modification account of word priming. Although this characterization of priming is possible, the theory is certainly unparsimonious. Furthermore, the present results demonstrate that nonword priming is not mediated by the same episodic memory processes that mediate recognition memory: If nonword priming and recognition memory were mediated by the same processes, then performance on the recognition and priming tasks should have been similarly affected by the levels-of-processing manipulation. They were not. Given the close correspondence between word and nonword priming in Experiment 1, it seems reasonable to conclude that similar mechanisms mediated both effects.

Although the present results provide preliminary evidence that implicit memory extends to legal nonwords, it is important to note that the recognition memory task followed the identification task at each study-test delay; consequently, there was a systematic confounding between the type of memory test and test order. It is not at all obvious how this confound could be responsible for the implicit-explicit dissociations observed with words and nonwords, but nevertheless, to address this issue directly, I carried out a control experiment with a separate group of 48 subjects from the University of Arizona. These subjects completed the same study and recognition memory tasks, but they completed the recognition task immediately after the study phase of the experiment. Consequently, performance on this control task provided an unconfounded measure of recognition memory that can be directly compared with the priming results in the 0-min delay condition of

Experiment 1. Not surprisingly, performance on the recognition task was higher when memory was assessed immediately after the study phase as opposed to after the identification task; nevertheless, the pattern of results in the various experimental conditions remained unchanged: Following the rhyme study conditions, subjects recognized a relatively high proportion of words (.61) and nonwords (.65), whereas following the structural encoding conditions, they recognized fewer words (.42) and nonwords (.38). These memory results and the priming results in the 0-min delay condition were subject to an ANOVA that included memory test as a between-subjects variable. As was the case in Experiment 1, the analysis revealed a strong Encoding Task $\times$ Memory Test interaction, $F(1, 88) = 24.48, p < .01, MS_e = 461.31$, thus indicating that the confound between test order and memory test was not responsible for the implicit–explicit dissociation obtained in the 0-min delay condition following the levels-of-processing manipulation. Because the earlier completion of the identification task does not appear to affect the pattern of the recognition memory results in the various experimental conditions, the confound of test order and memory test is not considered further (see Schacter, Cooper, et al., 1990, for additional evidence that test order effects do not influence the pattern of implicit and explicit memory dissociations).

Experiment 2

In addition to the implicit–explicit dissociation that is often obtained following a levels-of-processing manipulation, a number of studies have reported a dissociation following a study–test modality shift: Priming for words is greatly reduced following a modality shift, whereas explicit memory is generally intact (e.g., Jacoby & Dallas, 1981). As noted earlier, this dissociation has been important in developing theories of implicit memory phenomena (e.g., Morton, 1979; Schacter, 1990); consequently, it is important to determine whether this dissociation extends to legal nonwords. As in Experiment 1, I suggest that a similar pattern of results for words and nonwords indicates that similar mechanisms mediate priming for both materials.

In an initial attempt to assess the effects of a study–test modality shift on word and nonword priming, I carried out two pilot experiments in which subjects repeated or read items presented in the auditory and visual modalities, respectively. After the study phase, subjects completed either an identification or a recognition task in the visual modality. Similar results were obtained in both experiments. First, priming for words was absent or significantly reduced following a study–test modality shift, whereas recognition memory for words was intact. This dissociation between priming and recognition memory suggests that the word priming results were not mediated by explicit memory strategies. Second, priming for nonwords was absent or significantly reduced following the modality shift, but unlike the case of words, recognition memory for the nonwords was also reduced in the cross modality condition. In fact, performance on the identification and recognition tasks was equally reduced following the study–test modality shift, and accordingly, there was no evidence of an implicit–explicit memory dissociation for non-

words (see Bowers, 1993, for a complete description of the two pilot experiments). These nonword results are ambiguous. On one hand, the observation that word and nonword priming was modality specific suggests that similar mechanisms mediated both effects. On the other hand, the parallel results obtained with nonwords on the recognition and identification tasks leave open the possibility that nonword priming was the product of explicit memory strategies rather than implicit memory processes.

To avoid these ambiguous results, I devised a study procedure that produced robust recognition memory for nonwords following a study–test modality shift: If nonword priming remained modality specific under conditions in which recognition memory crossed modalities, then the priming results should be mediated by implicit rather than explicit memory strategies. To increase explicit memory for nonwords following a study–test modality shift, I confounded the levels-of-processing manipulation used in Experiment 1 with a study–test modality shift manipulation. As was the case in the pilot experiments, subjects studied a list of words and nonwords in the visual and auditory modalities. However, when items were presented in the auditory modality, subjects were asked to repeat the item out loud and then to think of as many rhymes as possible in 5 s. This study procedure directed subjects' attention to the phonetic aspects of the words and nonwords; consequently, it was expected to produce relatively good memory for these items. In contrast, when items were presented in the visual modality, subjects were asked to count the number of enclosed spaces and vowels in the item. This task emphasized the structural aspects of words and nonwords, and accordingly, recognition memory was expected to be poor for these items. After these study procedures, subjects completed the identification and recognition tasks. The critical question was whether an implicit–explicit dissociation would be obtained for words and nonwords under conditions that confounded a levels-of-processing manipulation with a study–test modality shift.

Method

Subjects. Forty-eight undergraduates from the University of Arizona were tested in Experiment 2. Subjects received course credit for their participation.

Design and materials. The design of Experiment 2 included three within-subject variables: lexicality (words vs. nonwords), encoding task (auditory–rhyme vs. visual–structure), and memory test (identification vs. recognition). Consequently, the experiment used a $2 \times 2 \times 2$ within-subject design.

The materials consisted of 30 legal nonwords and 30 words (median frequency = 18, range = 2–547 occurrences per million) selected from the Kucera and Frances (1967) norms. Words and nonwords were four letters in length and were selected so that no two items shared three letters in the same position. An additional constraint was observed in selecting the nonwords. Pilot experiments indicated that subjects had difficulty hearing a number of the nonwords that were presented in the auditory modality. For example, when subjects were asked to repeat the nonword *crel* a number of subjects responded “crii.” The perceptual difficulties associated with the nonwords posed a problem for the present design. As long as nonwords were difficult to hear, then recognition memory for the nonwords would continue to be reduced following the auditory study conditions. To resolve this problem, I

carried out a pilot experiment in which an initial sample of nonwords was presented on a tape recorder to a group of 10 subjects, and the subjects were asked to spell the items. Nonwords were only included in Experiment 2 if the experimenter and the 10 pilot subjects agreed on the spelling of the items.

During the study phase of the experiment, subjects studied 20 words and 20 nonwords; half of these items were presented in the visual and half were presented in the auditory modality. Items presented in the auditory modality were recorded on a tape recorder. The remaining 10 words and 10 nonwords were not studied; they were included both on the identification task to determine the baseline level of performance and on the recognition task as distractor items. Consequently, the identification task and the recognition task consisted of 60 critical items: 40 studied items (20 words and 20 nonwords), and 20 nonstudied items (10 words and 10 nonwords). Three test forms were created so that each word and nonword could be rotated through the auditory and visual study conditions, as well as the nonstudied condition, thus yielding a fully counterbalanced design.

Study items were blocked by modality so that subjects were exposed to 20 items in the auditory modality followed by 20 items in the visual modality (or vice versa). Furthermore, the presentation order of the items within each study block was reversed for different subjects. For example, if Subject A was presented with the items *rope*, *glot*, and *tire*, Subject B was presented with *tire*, *glot*, and *rope*. As was the case in Experiment 1, items in the identification task were presented in a fixed order, with words and nonwords randomly intermixed. Once again, items in the recognition task were presented in a random order.

Procedure. Experiment 2 was conducted under conditions of incidental encoding, and subjects were tested individually. In the first phase of this experiment, subjects completed an initial identification task that determined an exposure duration that resulted in an identification rate of 50% for words and nonwords in the baseline conditions. After this task, subjects were presented with the study list items in the visual and auditory modalities. In the auditory condition, items were presented every 5 s, and the sound of a bell preceded each item to warn subjects to stop generating rhymes and to listen for the next item. As noted earlier, this encoding condition was expected to lead to good explicit memory. In the visual study condition, items were presented for 5 s each, and subjects counted the number of enclosed spaces and vowels in each item. This encoding condition was expected to lead to poor explicit memory. Following the encoding phase of the experiment, subjects completed the identification recognition memory tasks (see Experiment 1 for a description of these tasks).

Results

The results of Experiment 2 are presented in Table 3 and Table 4. As was the case in the pilot experiments, priming was reduced in the condition that included a study-test modality

Table 3
Percentage of Words and Legal Nonwords Identified as a Function of Encoding Conditions in Experiment 2

Identification task	Lexicality			
	Words		Nonwords	
	Visual-Structural encoding	Auditory-Rhyme encoding	Visual-Structural encoding	Auditory-Rhyme encoding
Repeat	.65	.61	.58	.50
Nonrepeat	.55	.55	.49	.49
Priming	.10	.06	.09	.01

Table 4

Percentage of Words and Nonwords Recognized as a Function of Encoding Condition in Experiment 2

Recognition task	Lexicality			
	Words		Nonwords	
	Visual-Structural encoding	Auditory-Rhyme encoding	Visual-Structural encoding	Auditory-Rhyme encoding
Hits	.60	.76	.64	.76
False alarms	.42	.42	.49	.49
Hits - False alarms	.18	.34	.15	.27

shift, for both words and nonwords. In contrast with the pilot results, however, explicit memory was improved in this condition. This dissociation provides strong evidence that the priming results for both words and nonwords were not the result of explicit memory strategies.

Identification. Two aspects of the data seem noteworthy. First, significant priming was observed for words (.10) and nonwords (.09) in the visual-structural encoding condition (see Table 3), $t(47) > 2.51, p < .05, SE_M < 3.58$. Second, the priming effects were reduced or absent in the auditory-rhyme encoding condition: The priming effect for words (.06) just reached significance, $t(47) = 2.06, p < .05, SE_M = 2.73$, whereas there was no priming for nonwords (.01), $t(47) < 1$. When an ANOVA was carried out on these data, the main effect of the encoding task was the only effect that approached significance, $F(1, 15) = 6.52, p < .05, MS_e = 259.69$.

Recognition. Recognition memory for words and nonwords was similar in the various experimental conditions: Words and nonwords were recognized .34 and .27 in the auditory-rhyme condition (see Table 4), and .18 and .15 in the visual-structural condition, respectively. An ANOVA revealed a main effect of encoding task, $F(1, 45) = 14.98, p < .01, MS_e = 560.94$, but no other effects approached significance.

To test for an implicit-explicit memory dissociation, an overall ANOVA that included memory test as a within-subject variable was carried out. As expected, a strong Encoding Task $\times$ Memory Test interaction was observed, $F(1, 45) = 22.02, p < .01, MS_e = 400.31$, but the three-way interaction of Encoding Task $\times$ Memory Test $\times$ Lexicality did not approach significance, $F(1, 45) < 1$. These two results indicate that implicit and explicit memory dissociated for both words and nonwords. No other effects achieved significance in the overall ANOVA.

Discussion

The results of Experiment 2 are straightforward. Whereas priming was reduced for words and nonwords in the auditory-rhyme condition as compared with the visual-structural condition, recognition memory was facilitated. This pattern of results is particularly striking, because rather than a standard one-way dissociation, it reports a double dissociation: Improved recognition was associated with reduced priming, and improved priming was associated with reduced recognition. These results are reminiscent of an earlier implicit-explicit

double dissociation obtained with words (Jacoby, 1983b). In the Jacoby study, explicit memory was facilitated following a study condition that required subjects to generate the target word from an antonym (e.g., hot-c _____) compared with a condition in which they simply read the target item *cold*. In contrast, priming was reduced following the generate condition rather than the read condition. The present experiment extends this pattern of results to nonword materials and provides strong evidence that the nonword priming was not mediated by explicit memory strategies. Once again, these results favor an acquisition framework in which it is assumed that priming is mediated by new memory representations acquired in a single learning episode.

Experiment 3

To evaluate the relative merits of modification and acquisition theories of implicit memory, I assessed priming of legal nonwords in Experiments 1 and 2. Given the results, it could be argued that the data favor acquisition theories of implicit memory phenomena. It is important to note, however, that the validity of this conclusion depends on a hidden assumption in the above experiments; namely, it has been assumed that legal nonwords constitute novel materials, and any priming effects observed for these materials are the result of new representations that entered memory for the first time during the study episode. This assumption seems intuitively plausible, and the majority of studies that purport to assess priming novel information have included legal nonwords as target materials. However, if this assumption is proved to be incorrect and if it is determined that legal nonwords are processed or encoded by means of preexisting memory representations, then the priming effects observed for legal nonwords are ambiguous: Priming could be attributed to the establishment of new memory representations, or priming could be attributed to memory processes that activate or strengthen preexisting memory traces. Accordingly, before any firm conclusion can be drawn, it is important to explore the notion of novel information in more detail.

Although legal nonwords may in fact be examples of novel information, a recent debate in the word-recognition literature has suggested that the distinction between novel and preexisting representations is not entirely straightforward. The debate has centered on the representational format of words. On one hand, a number of theorists have adopted a lexical stance. According to these authors, separate and discrete representations exist for each word in our vocabulary (e.g., Forster, 1976; Morton, 1979), and the first stage of word recognition is to gain access to the appropriate lexical entry. The critical point for the present discussion, however, is that this approach assumes that words have preexisting representations and that nonwords do not. In contrast, some connectionist theorists have argued that word-recognition processes rely on distributed rather than lexical representations (e.g., Seidenberg & McClelland, 1989). According to this view, a connectionist network can learn to associate orthographic features of words with phonological and semantic information, but these associations are acquired at a sublexical level (i.e., representations of words do not exist as discrete memory traces but instead are emergent properties of associations between subword representations). An impor-

tant assumption of this approach is that words and legal nonwords have a similar representational status: The network processes information on the basis of subword features, and both words and legal nonwords possess similar subcomponents.

The debate regarding the nature of word representations is far from settled (cf. Besner, Twilley, McCann, & Seergobin, 1990). The resolution of this debate has implications for theories of priming. For example, if one assumes that priming is restricted to preexisting representations, then predictions regarding legal nonword priming effects depend on whether a lexical or sublexical view of word recognition is adopted. According to the lexical view, words have preexisting memory representations and legal nonwords do not; thus, priming should only be observed for words. This position seems to be compromised by the legal nonword priming results observed in Experiments 1 and 2. According to the sublexical view, however, words and legal nonwords share many of the same representations; consequently, it should be possible to observe priming for both types of materials. It can be argued that the legal nonword priming results are ambiguous with regard to theories of implicit memory: The priming results could be the result of establishing novel memory representations, or they could be the result of activating or strengthening preexisting sublexical memory representations.

Given this debate, it seems appropriate for researchers to assess priming of illegal nonwords in addition to legal nonwords. Illegal nonwords, as opposed to legal nonwords, do not share sublexical features with words, and consequently, these materials are novel from a sublexical perspective (i.e., the illegal nonword *kxql* does not possess familiar subcomponents beyond the individual letters). Consequently, priming effects obtained with illegal nonwords should provide much stronger evidence that new memory representations mediate implicit memory phenomena. In fact, at least two experiments have assessed illegal nonword priming. Rugg and Nagy (1987) compared priming effects for legal and illegal nonwords following a short study-test delay (study-test items were presented in succession) by using event-related potential (ERP) technology. The critical finding was that the ERP repetition effects were obtained for legal nonwords but not for illegal nonwords. On the basis of these findings, Rugg and Nagy argued that legal nonword priming is dependent on the sublexical similarities between legal nonwords and words. In addition, Schacter, Rapcsak, Rubens, Tharan, and Laguna, (1990) assessed priming for words and illegal nonwords in a patient with alexia who read words only in a letter-by-letter fashion. The patient was presented a list of words and illegal nonwords to study; the patient was allotted sufficient time to read each word in a letter-by-letter fashion. After the study task, the patient completed an identification task that allowed her to occasionally identify nonstudied items. The critical finding was that although priming was reported for words, there was no evidence of priming for illegal nonwords. Once again, these results are consistent with the view that priming is the result of modifying preexisting sublexical representations.

Although the studies described earlier failed to obtain priming for illegal nonwords, it is important to note that the Rugg and Nagy (1987) experiment used a different dependent

measure of priming than I used in the present experiments, and Schacter, Rapcsak, et al. (1990) used a different subject population. Thus, it seemed appropriate for me to assess priming of illegal nonwords under the present set of conditions. To this end, subjects in Experiment 3 encoded a list of legal and illegal nonwords structurally and phonetically, and after presentation of the study list, they completed both an identification and a recognition task. The critical questions were (a) whether robust priming would be observed for the illegal nonwords and (b) whether priming effects dissociate explicit memory.

Method

Subjects. Forty-eight undergraduates from the University of Arizona were tested in Experiment 3. Subjects received course credit or \$4 for their participation.

Design and materials. In Experiment 3 I included three within-subject variables: legality (legal vs. illegal nonword), encoding task (structural vs. rhyme), and memory test (identification vs. recognition). Consequently, the experiment had a $2 \times 2 \times 2$ within-subject design. The legal nonwords from Experiment 2 were used in Experiment 3, as well as a list of 30 illegal nonwords composed of random letter strings. The overall design of Experiment 3 was the same as that of Experiment 2.

Procedure. Once again, Experiment 3 was conducted under conditions of incidental encoding, and subjects were tested individually. In the initial phase of the experiment, subjects completed an identification task that determined the duration at which legal and illegal nonwords should be flashed on the computer screen. On the basis of the subjects' performance on this task, I presented the legal and illegal nonwords for 75 ms vs. 135 ms, 67 ms vs. 120 ms, and 58.5 ms vs. 105 ms in the slow, medium, and fast conditions, respectively. After the identification task, subjects completed the encoding task. Each item was presented for 5 s, and immediately preceding each item, the word *pronounce* or the words *vowels-spaces* was presented on the computer screen. Whenever the word *pronounce* preceded an item, subjects were asked to pronounce the item; then they were asked to rate how easy it was to pronounce the item on a scale ranging from *not at all difficult to pronounce* (1) to *extremely difficult to pronounce* (5). Whenever the words *vowels-spaces* were presented, subjects were asked to count the number of enclosed spaces and vowels in the item, just as in Experiment 1. The *pronounce* and *vowels-spaces* instructions composed the phonetic and structural encoding conditions, respectively. After the encoding phase of the experiment, subjects completed the identification and the recognition tasks.

Results

Tables 5 and 6 display the recognition and priming scores for legal and illegal nonwords in the various experimental and

Table 5
Percentage of Legal and Illegal Nonwords Identified as a Function of Encoding Condition in Experiment 3

Identification task	Legal nonwords		Illegal nonwords	
	Structural encoding	Phonetic encoding	Structural encoding	Phonetic encoding
Repeat	.56	.56	.48	.54
Nonrepeat	.40	.40	.41	.41
Priming	.16	.16	.07	.13

Table 6
Percentage of Legal and Illegal Nonwords Recognized as a Function of Encoding Condition in Experiment 3

Recognition task	Legal nonwords		Illegal nonwords	
	Structural encoding	Phonetic encoding	Structural encoding	Phonetic encoding
Repeat	.57	.82	.55	.74
Nonrepeat	.38	.38	.39	.39
Priming	.19	.44	.16	.35

control conditions. The results obtained with the legal nonwords were entirely consistent with Experiment 1: Priming of legal nonwords was similar following phonetic (.16) and structural (.16) study conditions (see Table 5), whereas recognition memory was much higher following phonetic (.44) compared with structural (.19) conditions (see Table 6). A 2×2 ANOVA that treated encoding task and memory test as within-subject variables revealed an interaction between priming and recognition memory, $F(1, 45) = 52.35, p < .01, MS_e = 145.66$.

In contrast with the clearcut dissociation between priming and recognition memory for legal nonwords, the illegal nonword results are somewhat ambiguous. As was the case with legal nonwords, subjects remembered more illegal nonwords following phonetic (.35) encoding than they did following structural (.16) encoding conditions (see Table 6). However, in contrast with the legal nonwords, illegal nonword priming was almost twice as great following phonetic (.13) encoding than it was following structural (.07) study conditions (see Table 5), although this difference did not achieve significance, $t(47) = 1.70, p > .05, SE_M = 3.19$. Nevertheless, the data provide evidence that recognition memory and priming for illegal nonwords were both sensitive to levels-of-processing manipulations.

The illegal nonword data were subjected to a 2×2 ANOVA that treated encoding task and memory test as within-subject variables. The interaction of Encoding Task $\times$ Memory Test was significant, $F(1, 45) = 9.34, p < .01, MS_e = 207.47$, indicating that the levels-of-processing manipulation influenced performance on the recognition task more than it did on the identification task. This interaction suggests that the priming effects obtained with illegal nonwords were not the result of explicit memory strategies: If illegal nonword priming was simply the result of explicit memory strategies, then performance on the recognition and priming tasks should have been similarly affected by the levels-of-processing manipulation; this was not the case.

Finally, to determine whether priming was significantly above baseline for legal and illegal nonwords in the structural and phonetic conditions, I carried out a series of t tests. Priming was significant in all cases, $t(47) > 2.24, p < .05, SE_M < 3.26$.

Discussion

Consistent with Experiment 1, robust priming was observed for legal nonwords, and the results dissociated from recognition memory. As noted earlier this result is problematic for

theories of implicit memory in which it is assumed that priming is the product of processes that modify preexisting lexical representations (e.g., Monsell, 1985). However, the legal nonword priming results are completely consistent with a modification theory in which it is assumed that priming is mediated by sublexical representations (e.g., Rugg & Nagy, 1987). As noted earlier, this latter view assumes that priming is the result of memory processes that activate or strengthen preexisting sublexical representations, and a critical feature of legal nonwords is that they are composed of familiar sublexical codes.

Although the sublexical account of priming can accommodate the legal nonword results, it is not clear that this approach is consistent with the illegal nonword findings. As was noted earlier, significant priming was observed for illegal nonwords following both structural and phonetic study conditions, and furthermore, the results dissociated from explicit memory. This result is important because illegal nonwords are composed of unfamiliar letter sequences; thus, the priming cannot be attributed to memory processes that activate or strengthen preexisting sublexical representations. To the extent that these priming results reflect implicit memory processes, the results provide strong evidence in support of the acquisition framework.

It must be admitted, however, that the present set of results do not support any strong theoretical conclusions. Although the levels-of-processing manipulation had a stronger effect on explicit than on implicit memory, there was nevertheless an indication that priming was stronger (albeit nonsignificantly) when following the phonetic rather than the structural encoding condition. In fact, priming was almost twice as large in the phonetic (.13) compared with the structural (.07) encoding condition. Because the levels-of-processing manipulation affected priming and recognition memory in the same general way, it is at least possible that all of the priming obtained for illegal nonwords was the result of explicit memory strategies, and the dissociation between priming and recognition memory was due to the relative difficulty of the two tasks, or to the product of the different dependent measures used in the two tasks. This argument is less plausible in the case of the legal nonwords, because priming was completely insensitive to the levels-of-processing manipulation, whereas explicit memory for these items was strongly affected by this variable.

It is unclear why the Rugg and Nagy (1987) and the Schacter, Rapsack, et al. (1990) studies failed to obtain priming with illegal nonwords, whereas significant priming was obtained with these materials in the present experiment. In the absence of more data, the different results can only be attributed to the very different experimental procedures that were used to assess priming in the above studies. Nevertheless, the fact that illegal nonword priming has only been observed in a subset of the conditions that support legal nonword priming suggests that there may be important differences between the memory processes that mediate legal and illegal nonword priming. Given these considerations, it is important to explore the characteristics of illegal nonword priming in more detail before any strong conclusions should be made regarding the mechanisms that underlie illegal nonword priming in the present test conditions.

Experiment 4

It is important to contrast the robust priming obtained with legal nonwords in Experiments 1–3 with a number of studies in which little or negative priming has been observed with legal nonwords when priming was assessed with the lexical-decision task (e.g., Bentin & Moscovitch, 1988; Forbach et al., 1974; McKoon & Ratcliff, 1979). As noted in the introduction, the failure to obtain nonword priming with the lexical-decision task may be the result of a response bias that interferes with task performance: Subjects should respond “nonword” to repeated nonwords, but the familiarity of these items biases subjects to respond “word” (Feustel et al., 1983). The key evidence in favor of this proposal is that nonword priming is generally observed in tasks other than the lexical-decision task (e.g., Feustel et al., 1983; Kirsner & Smith, 1974). However, this argument must be considered equivocal for two reasons. First, comparisons across experiments are always problematic. It is unclear whether the presence or absence of nonword priming on the identification–lexical-decision tasks is due to a difference in the tasks or to some other uncontrolled variable. Second, although the general trend has been to observe more priming for nonwords in the identification tasks compared with the lexical-decision task, there are nevertheless reports of robust nonword priming in the lexical-decision task (e.g., Monsell, 1985; Smith & Oscar-Berman, 1990) and of small effects in the identification task following a single study episode (e.g., Whitlow, 1990; Whitlow & Cebollero, 1989). These considerations led Monsell (1985) to question the response bias interpretation of Feustel et al. (1983). To provide a stronger test of the Feustel et al. argument, in Experiment 4 I assessed priming of nonwords with the lexical-decision task as opposed to the identification task, but I maintained the remaining procedures and materials as closely as possible to those used in Experiment 1. The only differences between the two experiments were that Experiment 4 included a larger set of words and nonwords, an immediate study–test delay but not the longer delay conditions, and a lexical-decision task rather than an identification task. If nonword priming is severely reduced or negative in Experiment 4 as compared with the results of Experiment 1 despite the fact that similar experimental conditions were used, then the results should provide strong evidence that priming for nonwords is selectively inhibited in the lexical-decision task. Such a result would help to explain the null priming effects obtained for legal nonwords when the lexical-decision task has been used (e.g., Bentin & Moscovitch, 1988); thus these past results would not compromise the present conclusion that implicit memory extends to legal nonwords.

Method

Subjects. Forty-eight undergraduates from the University of Arizona were tested in Experiment 4. Subjects received course credit for their participation.

Design and materials. Experiment 4 included three within-subject variables: lexicality (word vs. legal nonword), encoding task (structural vs. rhyme), and memory test (lexical decision vs. recognition). Consequently, the experiment had a $2 \times 2 \times 2$ within-subject design. The materials included the same set of 24 words and 24 nonwords that were

included in Experiment 1. However, an additional set of 24 words and 24 nonwords were included to increase the number of items per condition from 6 to 12. I considered 6 items per condition to be inadequate in a lexical-decision task because an item is dropped from the analysis whenever a subject incorrectly categorizes it as a word or a nonword. Accordingly, the experimental materials consisted of 48 legal nonwords and 48 low-frequency words (median frequency of the 48 words = 20 and range = 1–49 occurrences per million). All of the words and nonwords were four letters in length, and no items were orthographic neighbors.

During the study phase of the experiment, subjects studied 24 words and 24 nonwords. The remaining 24 words and 24 nonwords were not studied; they were included on the lexical-decision task to determine baseline levels of performance and on the recognition task as distractor items. Consequently, the lexical-decision task and the recognition task consisted of 96 critical items: 48 studied items (24 words and 24 nonwords) and 48 nonstudied items (24 words and 24 nonwords). Four test forms were created so that each word and nonword was rotated through the structural and rhyme study conditions, as well as the nonstudied condition, thus yielding a fully counterbalanced design. Items were presented in a random order during the encoding, lexical-decision, and recognition tasks.

Procedure. The experiment was conducted under conditions of incidental encoding, and subjects were tested individually. In the first phase of the experiment, subjects completed the encoding task. In each study trial, either the word *rhyme* or *structure* was presented for 1 s and was followed by a 5-s exposure of a word or nonword. As was the case with Experiment 1, subjects were instructed to count vowels and enclosed spaces when the word *structure* was presented, and they were asked to pronounce the item out loud and generate rhymes of the item when the word *rhyme* was displayed. Ten buffer trials were included in the study session: five primacy buffers at the beginning of the list and five recency buffers at the end.

After the study phase of the experiment, subjects completed the lexical-decision task. Items were presented in the center of the screen, and subjects were asked to press the right shift key on the keyboard as quickly as possible if the item was a word and to press the left shift key if it was a nonword. Finally, subjects completed the recognition task in which they were to press the right shift key if they remembered the item from the study list and to press the left shift key if they did not. As in earlier experiments, items remained on the screen until subjects responded.

Results

The results of Experiment 4 are displayed in Tables 7 and 8. As was the case with Experiment 1, words showed similar priming following the rhyme (28 ms) and structural (38 ms) encoding conditions (see Table 7), whereas recognition memory

Table 8

Percentage of Words and Legal Nonwords Recognized as a Function of Encoding Condition in Experiment 4

Recognition task	Lexicality			
	Words		Nonwords	
	Structural encoding	Rhyme encoding	Structural encoding	Rhyme encoding
Hits	.57	.76	.50	.71
False alarms	.47	.47	.37	.37
Hits – False alarms	.10	.29	.13	.34

was much higher following the rhyme (.29) condition than it was following the structural (.10) encoding condition (see Table 8). The critical finding of the present experiment, however, is that nonwords showed strong inhibitory priming following rhyme (–42 ms) and structural (–37 ms) encoding conditions (see Table 7), whereas the recognition memory results for nonwords were similar to the word results when following rhyme (.34) and structural (.13) encoding conditions (see Table 8).

A difficulty in analyzing these data is that priming was measured in RTs and recognition was measured in percentages correct. The different scales make comparisons across tasks problematic. Accordingly, separate ANOVAs were carried out on the lexical-decision task and on the recognition memory task. When the lexical-decision data were subjected to an ANOVA that included encoding task and lexicality as within-subject variables, the main effect of lexicality achieved significance, $F(1, 44) = 29.87, p < .01, MS_e = 8,375.22$. This result reflects the fact that the positive priming for words was significantly different from the negative priming for nonwords. In contrast, the encoding task variable did not approach significance, $F(1, 44) < 1$, which indicates that priming was insensitive to the levels-of-processing manipulation. To determine whether priming for words and nonwords was significantly different from 0, I computed a series of *t* tests. Significant priming was observed in all conditions, $t(77) > 2.55, p < .05, SE_M < 10.90$.

An ANOVA carried out on the recognition data revealed a main effect of the encoding task, $F(1, 44) = 71.77, p < .01, MS_e = 268.79$, thus indicating that the levels-of-processing manipulation had a strong effect on recognition memory. In contrast to the lexical-decision analysis, however, lexicality did not affect recognition performance, $F(1, 44) = 1.74, p > .05, MS_e = 438.04$. The finding that recognition memory was similar for words and nonwords is important, because it suggests that the different results obtained with words and nonwords in the lexical-decision task cannot be attributed to different levels of recognition memory for words and nonwords.

Discussion

Two findings are noteworthy in Experiment 4. First, the structural and phonetic (rhyme) encoding conditions produced a similar amount of facilitation for words on the lexical-decision task, whereas recognition memory was strongly affected by the levels-of-processing manipulation. This pattern

Table 7

Reaction Time (in Milliseconds) to Make Lexical Decisions With Words and Legal Nonwords as a Function of Encoding Condition in Experiment 4

Lexical-decision task	Lexicality			
	Words		Nonwords	
	Structural encoding	Rhyme encoding	Structural encoding	Rhyme encoding
Repeat	610	621	768	773
Nonrepeat	649	649	731	731
Priming	38	28	–37	–42

of results is consistent with the findings obtained in Experiment 1 where the identification task was used. Second, and in contrast with Experiment 1, robust inhibitory priming was observed for legal nonwords. In fact, a similar amount of inhibitory priming was observed following structural and phonetic (rhyme) encoding conditions, whereas recognition memory for these items showed the standard levels-of-processing effect. The contrast between the positive nonword priming in Experiment 1 and the inhibitory nonword priming in Experiment 4 is striking because the design and procedures of the two studies were similar. These results suggest that Feustel et al. (1983) were correct in arguing that the lexical-decision task includes a response bias that makes it difficult to categorize repeated nonwords as nonwords.

In addition to supporting the Feustel et al. (1983) argument with regard to the response bias, Experiment 4 provides some important constraints on the types of mechanisms that mediate positive and inhibitory priming in the lexical-decision task. According to Feustel et al., word and nonword priming is largely the result of episodic memory traces, and these traces are thought to facilitate yes responses to repeated words and to inhibit no responses to repeated nonwords in the lexical-decision task. However, the positive priming obtained with words in the present experiment dissociated from recognition memory following a levels-of-processing manipulation. Similarly, the inhibitory nonword priming dissociated from explicit memory following this manipulation. Thus, the priming obtained for words and nonwords was not mediated by the same episodic memory processes that mediated recognition memory. Instead, the priming results were mediated by processes insensitive to levels-of-processing manipulations.

Whatever the proper explanation for these results, the data have important implications for past experiments that have assessed nonword priming with the lexical-decision task. As noted in the introduction, a number of authors have failed to observe nonword priming with the lexical-decision task (e.g., Bentin & Moscovitch, 1988), and these results have been used to argue that priming is mediated by preexisting memory representations. However, the results of Experiment 4 support the view that a response bias acts to obscure priming for nonwords in the lexical-decision task. Accordingly, the failure to obtain nonword priming with the lexical-decision task may not compromise the present claim that implicit memory extends to legal nonwords.

General Discussion

Two classes of theories have been proposed to explain implicit memory phenomena: (a) modification theories that maintain that implicit memory is the result of activating or strengthening preexisting memory representations and (b) acquisition theories that maintain that implicit memory is the result of new memory representations. These two positions continue to be supported (see Carpenter & Grossberg, 1993, for modification viewpoint; Schacter, 1992, for acquisition viewpoint), and it is unlikely that important progress can be made toward understanding implicit memory phenomena until this issue is resolved.

The present experiments have yielded two main results that

are relevant to resolving this debate. First, robust priming was observed for legal nonwords, and these effects dissociated from explicit memory when following a levels-of-processing manipulation (Experiments 1 and 3) and when following conditions that confounded a levels-of-processing manipulation with a study-test modality shift (Experiment 2). These results are important, because previous studies with control subjects have not attempted to dissociate legal nonword priming from explicit memory, and consequently, it was possible that these effects were mediated partly, or perhaps entirely, by explicit memory strategies. The fact that priming dissociated from explicit memory in Experiments 1–3 indicates that the present results were not the result of explicit memory strategies. As noted earlier, these results are difficult to reconcile with the view that priming is the result of strengthening preexisting lexical representations (Monsell, 1985; Morton, 1969, 1979). However, the results are completely consistent with modification theories that assume that priming is the result of activating or strengthening preexisting sublexical level codes (e.g., Rugg & Nagy, 1987).

The second main result relevant to resolving this modification–acquisition debate is that priming extended to illegal nonwords, and these effects dissociated from explicit memory (Experiment 3). This result is important because illegal nonwords are not composed of preexisting sublexical representations; thus, the priming effects cannot be attributed to memory processes that activate or strengthen preexisting sublexical codes. To the extent that these priming results reflect implicit memory processes, the results provide strong evidence in support of the acquisition framework. Once again, however, it is important to emphasize that the present findings do not provide unequivocal support for the acquisition framework. Although a significant implicit–explicit dissociation was obtained for the illegal nonwords, there is some indication that priming was greater when following phonetic encoding conditions than it was when following structural encoding conditions—a result that was also obtained for explicit memory. Thus one cannot rule out the possibility that the priming results obtained with illegal nonwords were mediated by explicit memory strategies. If future experiments fail to obtain priming for illegal nonwords or if it is demonstrated that legal and illegal nonword priming effects are mediated by different mechanisms (e.g., illegal nonword priming is mediated by explicit memory strategies), then a modification framework will be supported.

Before I conclude, it is worth discussing some similarities between the present set of results and priming effects that have been obtained with novel nonverbal materials. As noted in the introduction, a number of experiments have assessed priming of novel objects and line patterns in an attempt to distinguish modification and acquisition theories of implicit memory (e.g., Gabrieli et al., 1990; Kroll & Potter, 1984; Musen & Triesman, 1990; Schacter, Cooper, et al., 1990; Schacter, Cooper, Delaney, et al., 1991; Schacter, Cooper, Tharan, et al., 1991); thus, it might be expected that this literature may help resolve the modification–acquisition debate. Unfortunately, however, much of this research suffers from the same basic problem that characterizes research in the verbal domain; namely, the experiments often include target materials that are inadequate

for distinguishing between the two theoretical frameworks. For example, Schacter, Cooper, et al. (1990; Schacter, Cooper, Delaney, et al., 1991; Schacter, Cooper, Tharan, et al., 1991) reported robust priming for line drawings of possible unfamiliar three-dimensional objects, and on the basis of these results, they argued that priming was the product of new representations acquired in a single study episode. As was the case in the verbal domain, however, the validity of this conclusion depends on a hidden assumption, namely, that the target materials are novel. Again, this assumption may not be justified. In the case of three-dimensional objects, the materials are novel when considered as complete units, but they can also be described as a set of object primitives (e.g., bricks, cones, and wedges; see Biederman, 1987) organized in novel combinations. In this respect, the three-dimensional objects are similar to legal nonwords—in both cases, the materials are unfamiliar, and they are composed of familiar primitives organized in familiar subpatterns. Thus, the priming obtained with novel three-dimensional objects may be the result of strengthening familiar subpatterns of object primitives rather than the result of constructing an entirely new memory representation. That is, the priming results obtained with novel three-dimensional objects are ambiguous with respect to modification-acquisition theories of implicit memory. A similar ambiguity may exist for the materials used by Gabrieli, Milberg, Keane, and Corkin (1990), Kroll and Potter (1984), and Musen and Triesman (1990); thus, the robust priming obtained with these materials does not provide unequivocal support for the acquisition framework.

In the present argument, the only way to distinguish acquisition and modification theories is to assess priming of novel materials that do not contain familiar subpatterns of primitives. In the verbal domain, illegal nonwords are a good example, the letter sequences in illegal nonwords do not occur within words. In the nonverbal domain, however, it is less clear what types of materials fit this description. One possibility is the set of impossible three-dimensional objects that Schacter and his colleagues (Schacter, Cooper, & Delaney, 1990) have studied. These objects contain subtle surface, edge, or contour violations that make them impossible to exist as actual three-dimensional objects. Accordingly, these objects cannot be described as a set of object primitives organized in familiar subpatterns. In this respect, impossible objects are similar to illegal nonwords, and they should provide a strong test of the acquisition framework.

Given this analysis, it is interesting to note that Schacter, Cooper, and Delaney (1990) have consistently failed to observe priming for impossible objects. The fact that priming is limited to possible objects provides evidence that priming may rely on the preexisting object primitives that exist in possible objects but that are absent in impossible objects. In other words, these null results provide some support for the modification framework. Of course, it is not appropriate to make any strong conclusion on the basis of these null results—the failure to show priming could be the result of a number of factors. For instance, Schacter, Cooper, et al. (1990) suggested that subjects cannot form mental representations of structural impossibility; thus, priming cannot be obtained for these materials. That is, the absence of priming is not due to the fact that

impossible objects are novel, but rather, it is because they are impossible. Another possibility is that the particular task that Schacter et al. used to assess priming selectively impaired priming for the impossible objects, much like the lexical-decision task selectively impaired priming for legal nonwords in Experiment 4. In the typical Schacter et al. experiment, subjects encoded a list of possible and impossible objects, and at test, the studied and nonstudied objects were flashed quickly on the computer screen. The subjects' task was to categorize objects as possible or impossible, and priming was measured as an improved ability to categorize studied as opposed to nonstudied objects—the so-called object-decision task. It is conceivable that subjects have a bias to say "possible" to repeated impossible objects, just as subjects have a bias to say "word" to repeated nonwords in the lexical-decision task. This bias would be adaptive under normal circumstances, because familiar objects are typically possible. However, this bias would impede performance in the object-decision task. Consequently, the null priming effects obtained with the impossible objects may simply be an artifact of the particular task demands of the object-decision task.

This discussion highlights a basic similarity between the research in the verbal and nonverbal domains; namely, in both areas, there has been little discussion regarding what constitutes novel materials, and as a consequence, many of the studies that purport to distinguish modification and acquisition frameworks are inconclusive. To date, few researchers have assessed priming for novel materials that cannot be described as a set of familiar primitives organized in familiar subpatterns, and these researchers have reported null priming effects (see Rugg & Nagy, 1987; Schacter, Rapcsak, et al., 1990, for null results obtained with novel verbal materials; see Schacter, Cooper, et al., 1990; Schacter, Cooper, Delaney, et al., 1991, for null results obtained with novel nonverbal materials). In contrast, significant priming was obtained for illegal nonwords in Experiment 3; thus the present results provide preliminary evidence that priming extends to novel information. However, additional research must be carried out in both the verbal and the nonverbal domains before any firm conclusions can be drawn regarding the modification-acquisition debate.

In summary, the present set of experiments indicates that implicit memory extends to legal nonwords and provides preliminary evidence that implicit memory extends to illegal nonwords as well. On the basis of the legal nonword results, I conclude that priming cannot be the result of memory processes that modify preexisting lexical representations. Similarly, on the basis of the illegal nonword results, I argue that priming cannot be mediated by preexisting sublexical representations. These findings tend to support the view that priming is the result of constructing new memory representations following a single study episode. However, further experiments with illegal nonwords must be carried out before any strong conclusions can be drawn.

References

- Bentin, S., & Moscovitch, M. (1988). The time course of repetition effects for words and unfamiliar faces. *Journal of Experimental Psychology: General*, 117, 148–160.

- Besner, D., Twilley, L., McCann, R. S., & Seergobin, K. (1990). On the association between connectionism and data: Are a few words necessary? *Psychological Review*, 97, 432-446.
- Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review*, 94, 115-147.
- Bowers, J. S. (1993). *Priming of nonwords in normal subjects*. Unpublished doctoral dissertation, University of Arizona.
- Bowers, J. S., & Schacter, D. L. (1990). Implicit memory and test awareness. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 404-416.
- Bowers, J. S., & Schacter, D. L. (1993). Priming of novel information in amnesic patients: Issues and data. In P. Graf & M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development, and neuropsychology* (pp. 303-326). Hillsdale, NJ: Erlbaum.
- Carpenter, G. A., & Grossberg, S. (1987). A massively parallel architecture for a self-organizing neural pattern recognition machine. *Computer Vision, Graphics, and Image Processing*, 37, 54-115.
- Carpenter, G. A., & Grossberg, S. (1993). Normal and amnesic learning, recognition and memory by a neural model of cortico-hippocampal interactions. *Trends in Neuroscience*, 16, 131-137.
- Carr, T. H., Brown, J. S., & Charalambous, A. (1989). Repetition and reading: Perceptual encoding mechanisms are very abstract but not very interactive. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 763-778.
- Cermak, L. S., Blackford, S. P., O'Connor, M., & Bleich, R. P. (1988). The implicit memory ability of a patient with amnesia due to encephalitis. *Brain and Cognition*, 7, 312-323.
- Cermak, L. S., Bleich, R. P., & Blackford, S. P. (1988). Deficits in the implicit retention of new associations by alcoholic Korsakoff patients. *Brain and Cognition*, 7, 312-323.
- Cermak, L. S., Talbot, N., Chandler, K., & Wolbart, L. R. (1985). The perceptual priming phenomenon in amnesia. *Neuropsychologia*, 23, 615-622.
- Challis, B. H., & Brodbeck, D. R. (1992). Level of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 595-607.
- Cofer, C. C. (1967). Conditions for the use of verbal associations. *Psychological Bulletin*, 68, 1-12.
- Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 104, 268-294.
- Diamond, R., & Rozin, P. (1984). Activation of existing memories in the amnesic syndromes. *Journal of Abnormal Psychology*, 93, 98-105.
- Feustel, T. C., Shiffrin, R. M., & Salasoo, A. (1983). Episodic and lexical contributions to the repetition effect in word identification. *Journal of Experimental Psychology: General*, 112, 309-346.
- Forbach, G. B., Stanners, R. F., & Hochhaus, L. (1974). Repetition and practice effects in a lexical decision task. *Memory & Cognition*, 2, 337-339.
- Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds.), *New approaches to language mechanisms* (pp. 257-287). Amsterdam: North Holland.
- Fowler, C., Napps, S. E., & Feldman, L. (1985). Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Memory & Cognition*, 13, 241-255.
- Gabrieli, J. D. E., & Keane, M. M. (1988). Priming in the amnesic patient H. M.: New findings and a theory of intact and impaired priming in patients with memory disorders. *Society of Neuroscience Abstracts*, 14, 1290.
- Gabrieli, J. D. E., Milberg, W., Keane, M. M., & Corkin, S. (1990). Intact priming of patterns despite impaired memory. *Neuropsychologia*, 28, 417-428.
- Gordon, B. (1988). Preserved learning of novel information in amnesia: Evidence for multiple memory systems. *Brain and Cognition*, 7, 257-282.
- Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior*, 23, 553-568.
- Graf, P., Mandler, G., & Haden, P. (1982). Simulating amnesic symptoms in normal subjects. *Science*, 218, 1243-1244.
- Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 501-518.
- Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 385-395.
- Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 164-178.
- Haist, F., Musen, G., & Squire, L. R. (1991). Intact priming of words and nonwords in amnesia. *Psychobiology*, 19, 275-285.
- Jackson, A., & Morton, J. (1984). Facilitation of auditory word recognition. *Memory & Cognition*, 12, 568-574.
- Jacoby, L. L. (1983a). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 9, 21-38.
- Jacoby, L. L. (1983b). Remembering the data: Analyzing interaction processes in reading. *Journal of Verbal Learning and Verbal Behavior*, 22, 485-508.
- Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 110, 306-340.
- Kirchner, K., & Smith, M. C. (1974). Modality effects in word identification. *Memory & Cognition*, 2, 637-640.
- Kroll, J. F., & Potter, M. C. (1984). Recognizing words, pictures, and concepts: A comparison of lexical, object, and reality decisions. *Journal of Verbal Learning and Verbal Behavior*, 23, 39-66.
- Kucera, M., & Francis, W. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.
- McKoon, G., & Ratcliff, R. (1979). Priming in episodic and semantic memory. *Journal of Verbal Learning and Verbal Behavior*, 18, 463-480.
- Monsell, S. (1985). Repetition and the lexicon. In A. W. Ellis (Ed.), *Progress in the psychology of language* (Vol. 2, pp. 145-195). Hillsdale, NJ: Erlbaum.
- Monsell, S. (1987). Non-visual orthographic processing and the orthographic lexicon. In M. Coltheart (Ed.), *Attention and performance* (Vol. 12, pp. 299-323). Hillsdale, NJ: Erlbaum.
- Morton, J. (1969). The interaction of information in word recognition. *Psychological Review*, 76, 340-354.
- Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kollers, M. E. Wrolstad, & H. Bouma (eds.), *Processing models of visible language* (pp. 259-268). New York: Plenum.
- Murre, J. M. J. (1992). *Learning and categorization in modular neural networks*. Hillsdale, NJ: Erlbaum.
- Musen, G., & Squire, L. R. (1991). Normal acquisition of novel verbal information in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 17, 1095-1104.
- Musen, G., & Triesman, A. (1990). Implicit and explicit memory for visual patterns. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 127-137.
- Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology*, 36, 475-543.
- Roediger, H. L., III. (1990). Implicit memory: Retention without remembering. *American Psychologist*, 45, 1043-1056.
- Roediger, H. L., III., & Blaxton, T. A. (1987). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and cognitive processes*:

- The Ebbinghaus Centennial Conference* (pp. 349–379). Hillsdale, NJ: Erlbaum.
- Roediger, H. L., III., & Weldon, M. S. (1987). Reversing the picture superiority effect. In M. A. McDaniel & M. Pressley (Eds.), *Imagery and related mnemonic processes: Theories, individual differences, and applications* (pp. 151–174). New York: Springer-Verlag.
- Rozin, P. (1976). A psychobiological approach to human memory. In M. R. Rosensweig & E. L. Bennett (Eds.), *Neural mechanisms of memory and learning* (pp. 3–48). Cambridge, MA: MIT Press.
- Rueckl, J. G. (1990). Similarity effects in word and pseudoword repetition priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 374–391.
- Rugg, M. D., & Nagy, M. E. (1987). Lexical contribution to non-word repetition effects: Evidence from event-related potentials. *Memory & Cognition*, 15, 473–481.
- Salasoo, A., Shiffrin, R. M., & Feustel, T. C. (1985). Building permanent memory codes: Codification and repetition effects in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 50–77.
- Scarborough, D. E., Gerard, L., & Cortese, C. (1979). Accessing lexical memory: The transfer of word repetition effects across task and modality. *Memory & Cognition*, 7, 3–12.
- Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 501–518.
- Schacter, D. L. (1990). Perceptual representation system and implicit memory: Toward a resolution of the multiple memory debate. In A. Diamond (Ed.), *Annals of the New York Academy of Sciences: Vol. 608. The development and neural bases of higher cognitive function* (pp. 543–571). New York: New York Academy of Sciences.
- Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. *American Psychologist*, 47, 559–569.
- Schacter, D. L., Bowers, J. S., & Booker, J. (1989). Intention, awareness, and implicit memory: The retrieval intentionality criterion. In S. Lewandowsky, J. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 47–65). Hillsdale, NJ: Erlbaum.
- Schacter, D. L., Cooper, L. A., & Delaney, S. M. (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. *Journal of Experimental Psychology: General*, 119, 5–24.
- Schacter, D. L., Cooper, L. A., Delaney, S. M., Peterson, M. A., & Tharan, M. (1991). Implicit memory for possible and impossible objects: Constraints on the construction of structural descriptions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 17, 3–19.
- Schacter, D. L., Cooper, L. A., Tharan, M., & Rubens, A. B. (1991). Preserved priming of novel objects in patients with memory disorders. *Journal of Cognitive Neuroscience*, 3, 118–131.
- Schacter, D. L., Rapcsak, S., Rubens, A. B., Tharan, M., & Laguna, J. (1990). Priming effects in a letter-by-letter reader depend upon access to the word form system. *Neuropsychologia*, 28, 1079–1094.
- Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, 96, 523–568.
- Shimamura, A. P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology*, 38A, 619–644.
- Smith, M. E., & Oscar-Berman, M. (1990). Repetition priming of words and pseudowords in divided attention and in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 1033–1042.
- Squire, L. R. (1987). *Memory and brain*. New York: Oxford University Press.
- Underwood, B. J. (1964). Degree of learning and the measurement forgetting. *Journal of Verbal Learning and Verbal Behavior*, 3, 112–129.
- Whitlow, J. W. (1990). Differential sensitivity of perceptual identification for words and pseudowords to test expectations: Implications for the locus of word frequency effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 837–851.
- Whitlow, J. W., & Cebollero, A. (1989). The nature of word frequency effects on perceptual identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 643–656.
- Whittlesea, B. W. A., & Cantwell, A. L. (1987). Enduring influence of the purpose of experiences: Encoding–retrieval interactions in word and pseudoword perception. *Memory & Cognition*, 15, 465–472.

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