Journal of Memory and Language **45,** 585–615 (2001)
doi:10.1006/jmla.2001.2792, available online at http://www.academicpress.com on IDEAL®

A Comparison of Forgetting for Conscious and Automatic Memory Processes in Word Fragment Completion Tasks

Dawn M. McBride, Barbara Anne Dosher, and Nicole M. Gage

University of California, Irvine

Differential forgetting rates have been used as one argument for separable memory systems for implicit and explicit memory. In a previous study (McBride & Dosher, 1997), however, stem completion performance showed similar forgetting rates for both implicit and explicit instructions. The current study evaluated forgetting for implicit and explicit word-fragment completion. In Experiment 1, forgetting rates were compared for implicit and explicit task performance. Forgetting rates did not differ significantly between the two tasks. In Experiment 2, conscious and automatic memory estimates derived from multinomial models for process dissociation were compared. Forgetting rates for conscious and automatic memory processes did not differ significantly when estimated by a Jacoby equation-based model or by a guessing-elaborated model. Results indicate that forgetting is similar for conscious and automatic memory processes when measured with a fragment completion task for delays up to 45 min.

Key Words: implicit memory; priming; forgetting.

The focus of many recent studies in memory has been to discover and explain differences found between implicit and explicit task performance (see Roediger & McDermott, 1993, for a review). Explicit tasks require conscious recollection on the part of the subject. Typical examples of such tasks are free recall, cued recall, and recognition. Implicit memory tasks, on the other hand, involve memories of prior episodes that are accessed unconsciously or automatically. Some common implicit tasks include word-stem and word-fragment completion, where subjects are instructed to complete an item (stem or fragment) with the first word that comes to mind. Task performance for studied items is compared with an unstudied condition to determine the influence of memory on task performance. Alternatively, process dissociation methods (Jacoby, 1991) may be used to estimate automatic and conscious contributions to memory performance. The current study investigates the properties of forgetting with fragment completion tasks over retention intervals from 1 to 45 min in order to assess claims of dramatically different forgetting rates in implicit and explicit memory.

Address correspondence and reprint requests to Dawn M. McBride, Department of Psychology, Illinois State University, Campus Box 4620, Normal, Illinois 61790-4620. E-mail: dmmcbri@ilstu.edu.

Performance Dissociations

Research comparing implicit and explicit memory has shown numerous dissociations between performance on the two types of tasks. For example, a levels of processing effect is typically found for explicit tasks, but not for implicit tasks (e.g., Roediger, Weldon, Stadler, & Riegler, 1992). In addition, Craik, Moscovitch, and McDowd (1994) found differences in performance for implicit and explicit memory tasks based on study modality (visual or auditory). Changing modality from study to test affected implicit performance but did not affect explicit performance. Even more compelling are comparisons between amnesic and normal subjects. Researchers (Jacoby & Witherspoon, 1982; Warrington & Weiskrantz, 1970, 1974) have found that although amnesics show decremented performance for explicit tasks, their performance on implicit tasks is equivalent in most cases to that of normal subjects. These results have been taken to indicate that while brain areas involved in conscious recollection may be damaged, brain areas involved in unconscious (or automatic) memory have been spared in these subjects.

0749-596X/01 $35.00

Memory Systems View

Based on results from studies with both normal and amnesic subjects, Schacter (1987, 1992; Schacter & Tulving, 1994) and others (Squire, 1994, 1995; Squire & Knowlton, 1994; Squire, Knowlton, & Musen, 1993; Tulving & Schacter, 1990; Tulving, Schacter, & Stark, 1982) claim dissociations of implicit and explicit tasks can be interpreted as evidence of separable memory systems for implicit and explicit memory. Squire and his colleagues (Squire, 1994, 1995; Squire & Knowlton, 1994; Squire et al., 1993) have labeled these systems as nondeclarative priming and declarative fact memory, respectively. The criteria for distinguishing a separate system, however, are under debate (see Weldon, 1999, for a summary of views). Dosher and Rosedale (1991), Nadel (1994), and Schacter and Tulving (1994) independently propose criteria for a separable memory system. One criterion common to the three proposals is that of differing rates of forgetting. Producing evidence of substantially different forgetting rates, then, is an agreed-upon method of supporting a memory systems view.

Review of Forgetting Results

Differing forgetting rates have been claimed for performance on implicit and explicit tasks. In particular, Schacter (1987) has stated that word-stem completion performance declines more rapidly than explicit task performance (usually recognition), while performance on word-fragment completion tasks declines more slowly over time. Schacter's claim for fragment completion tasks was based on studies that compared performance on explicit tasks with performance on fragment completion tasks for various delays. For example, Tulving et al. (1982) compared fragment completion performance with performance on a recognition test for delays of 1 h and of 7 days. It was found that recognition performance declined considerably between test delays, while fragment completion performance remained relatively unchanged. These results were taken as evidence for a slower decay rate for fragment completion as compared to recognition. However, with regard to Schacter's claim about performance on stem completion tasks, McBride and Dosher (1997) reported similar forgetting for implicit and explicit stem completion tasks. Word stem completion performance was measured under both instruction types in several experiments. The form of forgetting function and the rate of forgetting were both essentially equivalent. Performance for both tasks (implicit and explicit) was found to decline rapidly between 1 and 15 min, but very slowly between 15 and 90 min. These results were supported by a second set of experiments measuring conscious and automatic memory processes in a process dissociation paradigm (McBride & Dosher, 1999). These studies indicate that, contrary to Schacter's (1987) claim of a quicker decline for implicit stem completion performance, implicit and explicit memory decline at a similar rate in word stem completion tasks. Further, these studies were an improvement over previous studies examining stem completion due to the measurement of performance at many retention intervals and a more comparable explicit comparison task (word-stem cued recall). However, the McBride and Dosher (1997, 1999) results do not speak to Schacter's second claim that implicit fragment completion performance declines more slowly than performance on explicit tasks.

A number of recent studies have examined forgetting for fragment completion tasks (for example, Craik et al., 1994; Komatsu & Ohta, 1984; Olofsson, 1995; Roediger & Blaxton, 1987; Roediger et al., 1992; Sloman, Hayman, Ohta, Law, & Tulving, 1988; Squire, Shimamura, & Graf, 1987; Tulving et al., 1982). A graphical summary of these results appears in Fig. 1. Unfortunately, a precise measurement of forgetting for implicit and explicit tasks was not the goal of most of these studies, and performance was measured for relatively few retention intervals (see Sloman et al., 1988, for an exception). In addition, performance on the implicit fragment completion test was often compared with performance on a recognition task. The Komatsu and Ohta (1984), Sloman et al. (1988), Squire et al. (1987), and Tulving et al. (1982) studies make such a comparison. Recognition differs in the type of response required and the range of possible performance. A comparison of fragment completion and recognition is complicated by both of these factors. Fragment completion performance ranges from baseline values (which depend on the difficulty of the fragments and the number of solutions possible

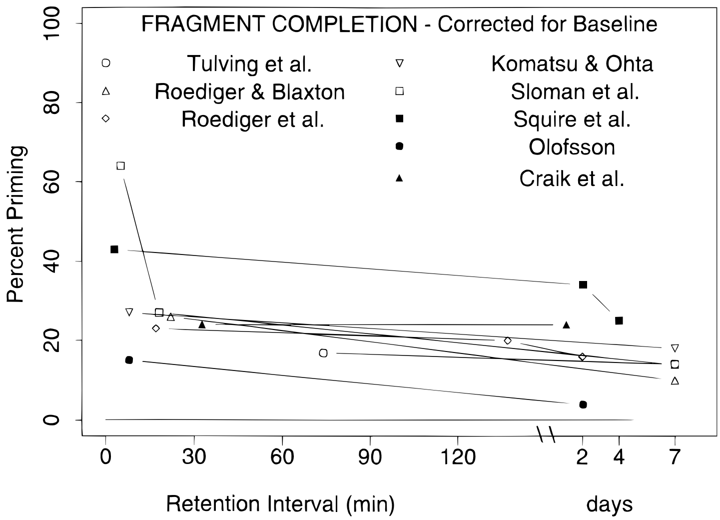

FIG. 1. Summary graph of percent priming data from experiments reporting forgetting results for word-fragment completion performance.

for each fragment) to 100%. Reported baseline values for the experiments listed above ranged from 2 to 31.6%. Recognition performance, on the other hand, usually ranges from 50 to 100%, a smaller range of values than that available for fragment completion. More importantly, fragment completion requires processes that involve the production of a word response based on letter cues, while recognition tasks require a judgment of “old” or “new” for given items. This most likely results in a large difference in retrieval processes for the two tasks. Therefore, recognition may not be the most consistent explicit task with which to compare implicit fragment completion performance. The current study follows the guideline of varying only the instructions, while equating the stimulus and response format. This procedure satisfies the retrieval intentionality criterion proposed by Schacter, Bowers, and Booker (1989) for valid comparisons of implicit and explicit task performance.

Additionally, the results shown in Fig. 1 are based on experiments where performance is measured for relatively few retention intervals. In order to accurately measure the rate of forgetting, a larger number of data points are required to measure the forgetting function. As is clear in Fig. 1, most studies measured performance first at about 30 min after study and then not again until days had passed. Although performance is consistent and did not appear to decline much in this range, it is unknown what levels of performance exist outside of this range.

One notable exception is the study conducted by Sloman et al. (1988). They measured performance on a fragment completion task for very short test delays (less than 5 min) and showed a very rapid decline in performance between 1 min and about 15 min (Sloman et al.’s data are displayed in Fig. 1). For delays longer than 15 min, performance declined very slowly. McBride and Dosher (1997) reported similar results for stem completion tasks. Performance for implicit and explicit tasks was found to decline rapidly between 1 and 15 min, but very slowly between 15 and 90 min. Therefore, implicit memory as measured by a fragment completion task may show rates of forgetting similar to explicit memory, but in a range of delays that have yet to be thoroughly tested.

The Current Study

The current study was designed to systematically measure forgetting with implicit and explicit fragment completion tasks. Although some studies have shown similar performance for fragment and stem completion tasks using manipulations such as study modality (Rajaram & Roediger, 1993) and level of processing (Roediger et al., 1992), several differences in processing exist for the two task types. Word fragments in previous reports often have only one possible solution, while word stems usually have three to five or more possible solutions. In addition, words are often more easily generated to three-letter stems than to fragments. Fragment completion may be more of a problem-solving task than is stem completion. Due to these differences, it is important to carefully measure forgetting rates with implicit and explicit fragment completion tasks, as was done for stem completion tasks (McBride & Dosher, 1997, 1999) to determine if previously claimed differences in forgetting rate do in fact exist for this task. Most important, however, is the view that differences in forgetting rate for implicit memory as measured by fragment completion and explicit memory are especially strong (Tulving & Schacter, 1990). Two experiments were conducted to compare forgetting rates for conscious and automatic memory processes involved in this task. In the first experiment, subjects were given a fragment completion task with either explicit instructions (complete the fragment with a studied item) or implicit instructions (complete the fragment with the first word you think of). Forgetting rates were estimated with power function fits to the task performance at several study–test delays. Subjects studied target items and completed fragments in a long trial sequence. Trial type (study and test) alternated in a random sequence. Number of intervening trials between study and test for each target item determined the retention interval for that item. This procedure was necessary to accurately measure completion performance for several study–test delays. Forgetting functions were fit to the performance data for delays of approximately 1 to 45 min.

Levels of processing effects. A traditional level of processing manipulation was used to evaluate the type of processing used in these experiments. As stated earlier, many studies have found no effect of level of processing on implicit tasks. Roediger et al. (1992) was an example of such a study. Performance was greater for words after semantic study than graphemic study on an explicit fragment test, but equivalent to graphemic study on an implicit fragment test. Challis and Brodbeck (1992), however, reported that under some conditions implicit tasks do show levels of processing effects. They presented a summary of previous literature showing that a small (often nonsignificant) levels of processing effect is seen in most studies using word-fragment completion, word-stem completion, or perceptual identification. In addition, two studies (Squire et al., 1987; Srinivas & Roediger, 1990) reported a significant levels of processing effect on implicit fragment completion tasks, where semantic study resulted in better performance than graphemic study. In experiments investigating conditions yielding levels of processing effects in implicit tasks, Challis and Brodbeck reported that when experiments are designed with levels of processing instructions given between subjects or within subjects in a blocked format, implicit fragment completion tasks can show significant levels of processing effects.

Brown and Mitchell (1994) also summarized 38 studies of implicit memory that used a levels of processing study manipulation. Eight of these studies measured implicit memory with a word fragment completion task. According to Brown and Mitchell, half of these studies reported some significant levels of processing difference in priming such that semantic study resulted in more priming than a study task that did not require semantic processing. Their meta-analysis for all tasks indicated that this effect did not depend on how the study task was manipulated (within- or between-subjects).

One possible explanation of significant levels of processing effects for perceptual implicit tasks may be that task performance is contaminated by explicit retrieval. In other words, subjects may in fact be consciously retrieving items from the study episode when completing the fragments, despite the implicit instructions to respond with the first item that comes to mind. Hamann and Squire (1996) investigated this explanation in a study comparing the performance of amnesics and controls on stem and fragment completion tasks. In all three experiments, nonamnesic controls showed levels of processing effects on the implicit tasks, but amnesics did not. Since amnesics are presumably incapable of conscious retrieval, whereas control individuals are capable, Hamann and Squire claimed that these results indicate explicit contamination on the implicit tasks, and that this may be an explanation of the results reported by Challis and Brodbeck (1992).

Toth, Reingold, and Jacoby (1994) pursued another approach to the investigation of this issue. They applied Jacoby's (1991) process dissociation procedure to a stem completion task in order to estimate conscious and automatic memory processes. This procedure allows for the comparison of the memory processes themselves, rather than relying for theoretical conclusions on task performance that may involve a mixture of implicit and explicit processing. Subjects studied items under semantic or graphemic study instructions and then were given tasks that allowed the estimation of conscious and automatic memory processes. Toth et al. reported the following results: Conscious estimates were higher for semantic than graphemic study, but automatic estimates did not differ for the two study conditions. The authors concluded that when "process pure" estimates of memory are obtained, unconscious or automatic forms of memory show no effect of level of processing.

In Experiment 1 of the current study, subjects were presented with target words with semantic or graphemic instructions. Traditional implicit and explicit word fragment completion tasks tested implicit and explicit memory for the target words to compare forgetting rates for the two memory processes with retention delays of 1 to 45 min. Due to the possibility of cross-process contamination on the implicit and explicit tasks (Hamann & Squire, 1996), Experiment 2 was conducted to evaluate forgetting rates for "process pure" conscious and automatic forms of memory used on the tasks in Experiment 1. Jacoby's (1991) process dissociation procedure and multinomial process tree models were used to estimate latent conscious and automatic memory processes in order to compare forgetting rates.

EXPERIMENT 1

Experiment 1 compared forgetting rates for explicit and implicit memory processes as measured by explicit and implicit word fragment completion tasks to evaluate the claim that implicit memory has a slower rate of decay than explicit memory when fragment completion tasks are used.

Method

Participants. Thirty-nine UC Irvine students volunteered as participants for Experiment 1. Forty-five participants received a brief typing test; however, data were analyzed only for participants ($N = 39$) with typing speeds of 25 words per minute or greater. Twenty-one subjects received implicit task instructions and 18 received explicit instructions. In addition, 14 separate subjects completed fragments without a study phase in order to determine baseline completion rates to facilitate compilation of the target item list used in the experiment. All subjects were native speakers of English.

Materials and design. One hundred and sixty words were chosen as target words based on the pre-experimental norming. Each word was five or six letters in length and allowed a fragment with at least three solutions. In this regard, the stimuli in the present study differ from some recent studies where stimuli included a combination of both multiple- and single-solution fragments (e.g., Srinivas & Roediger, 1990) or contained only single-solution fragments (e.g., Tulving et al., 1982). (An exception to this is provided in a study by Olofsson, 1995, who compared subjects' performance on single- and multiple-solution fragments.) Target completion words were selected for each fragment so as to reduce the baseline completion rate and hence maximize the possible performance range; the most common solution for each fragment during norming was never chosen as the target item. This target assignment, along with the selection of multiple-solution fragments, was intended to provide a better measure of the effect of priming and to reduce potential explicit contamination that could result from problem-solving strategies employed in the completion of single-solution fragments.

Fragments were created by deleting two to four letters from each word. Fragments were chosen from pre-experimental norming that allowed an average target completion rate of 11.4% with a range of 0 to 28.6%. No solution (target or alternative) could be used to complete more than one fragment. See Appendix A for a complete list of target stimuli and fragments used for both experiments. Another set of items was chosen from a list of filler items for filler trials (see below).

Filler items were chosen such that no item could be used to complete any word fragment.

Trial order and item assignment to conditions were randomly determined. This random assignment was repeated for each subject. Therefore, each subject received a different assignment of items to conditions. Over subjects, items were equally likely to be tested at all delays. For each subject, 140 target words were chosen as study items. Seventy study items were randomly assigned to the semantic instruction condition, and the other seventy were assigned to the graphemic study condition. Subjects were tested in total with 160 fragments (including 20 items not studied), all with one of the two test instructions (implicit or explicit). All study items ($N = 140$) were tested with fragment completion trials. In addition to those study items, 20 fragments representing the remaining unstudied target items were tested. Items were positioned within the 320-trial sequence randomly such that a certain number of trials intervened between the study trial and the test trial. Exposure–test lags included 5, 10, 15, 40, 80, 120, and 240 intervening "trials." A trial could include a single fragment test trial, a target item exposure and a vowel counting filler (see below), or two vowel counting filler items. Trials were defined in this way in order to control temporal and processing intervals of fragment completion and study exposures, as described below. Each study trial was immediately followed by a vowel counting filler trial, and several extra pairs of vowel counting trials were spaced throughout the trial sequence. Therefore, the study and test trials were embedded within a 320-trial sequence with vowel counting trials for filler words that were never tested. Subjects continued in a similar form of processing throughout the trial sequence.

In the 320-trial sequence, all of the 140 study trials included double stimulus presentations (as described above, each study trial was followed by a filler trial with a new word presentation). Overall then, subjects typically saw 480 items during the full sequence. During the sequence, 140 old (studied) items were tested in the fragment completion task. The average target fragment completion rate across lags, study conditions, and subjects on the implicit task was 37%; therefore, on average, subjects completed approximately 52 of the 140 fragments with old (studied) items. This indicates that only about 10% of the 480 total items in a full trial sequence could appear to be repeated to the subject (in the form of a completed fragment with an item he or she saw before). This low rate of repetition should hide the nature of the experiment from the subject.

Procedure. Stimulus presentation and response collection were controlled by a PC computer. Subjects received a sequence of 320 total trials. One hundred and forty trials were target word study trials (70 of each instruction type), 160 trials were fragment completion target test trials, and 20 trials were filler trials with a vowel counting task. For semantic study, subjects saw a "!" signature on either side of the word and were instructed to rate the word for pleasantness on a scale of 1 to 7 (1 = least pleasant, 7 = most pleasant). For graphemic study, subjects saw a "#" signature and were asked to count the number of ascending letters. For vowel counting filler items, subjects saw a "V" signature. A cue card mounted on the computer reminded subjects of the task instruction for each symbol. For the three trial types, the instruction signature appeared alone for 710 ms and then the word appeared with the signature for 2.5 s. If the word disappeared before a response was recorded, the program waited for a response before displaying the next item. Each target word study item was immediately followed by a vowel counting filler item in order to keep study and test trial timing consistent. Therefore, after a response was collected for each target study item (with either semantic or graphemic study instructions), a vowel counting signature appeared with a filler word item. The timing of both events combined was approximately equivalent to the timing for fragment completion test trials. Likewise, vowel counting filler trials included two items, both with vowel counting instructions.

Fragment completion trials were preceded by a fixation square in the center of the screen for 425 ms. Then a fragment appeared alone on the screen. Missing letters were replaced with an underscore. Fragments remained on the screen for 7 s. If subjects were assigned to the implicit task condition, they were asked to complete the fragments with the first word they could think of. For the explicit task condition, subjects were instructed to complete the fragment with a word they had seen in one of the other tasks. Guessing was not encouraged on the explicit task. Subjects received either implicit or explicit test instructions. For both tasks, subjects were asked to respond with "xxx" if they could not think of a solution before the fragment disappeared. Subjects were instructed to complete all tasks as quickly as possible.

Timing estimates. As stated above, in order to keep the timing of study and test trials consistent, all target study items were immediately followed by a filler item with vowel counting instructions. Therefore, maximum timing for a study-vowel pair was 6.2 s, while maximum timing for fragment test trials was 7.4 s. In this way, all trial types were considered similar for timing estimate purposes, with a study-vowel pair considered as one trial. During piloting, all trial types were found to have similar timing. Subjects entered the time off a digital clock every 80 trials to allow delay estimates. These times were used to determine the average retention delay for study–test lags of 5, 10, 15, 40, 80, 120, and 240 trials. Time estimates for these lags were 0.95, 1.89, 2.84, 7.57, 15.10, 22.65, and 45.40 min, respectively. Time estimates were calculated by determining time per trial for each subject and then averaging times across subjects. Timing was similar for subjects with implicit (0.1897 min/trial) and explicit (0.1889 min/trial) instructions.

Results and Discussion

Figure 2 displays the average proportion of fragments completed with target items for implicit and explicit task instructions. Different symbols show data for semantic and graphemic study conditions. Time delays cover a range of approximately 1 to 45 min. Evident in Fig. 2 is a rapid decline in target production up to about 12–15 min, and then a slower decline up to 45 min. These data are strikingly similar to forgetting data reported by McBride and Dosher (1997) for stem completion tasks. Subjects responded with target items on 10.7% of fragments where the target had not been studied. This result is comparable to the 11.4% baseline rate found in the pilot study. Above baseline target production reflects memory for studied items.

A three-way ANOVA was conducted for test type, study type, and lag variables. Main effects

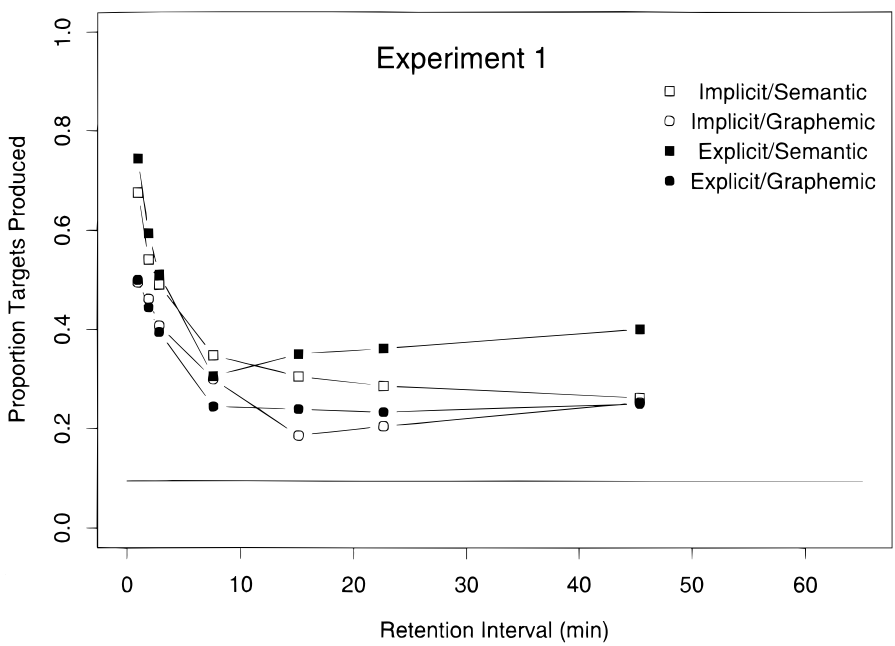

FIG 2. Proportion correct data from Experiment 1 for implicit and explicit fragment completion tasks as a function of test delay. Each line represents a different study/test condition.

of study type, $F(1,37) = 41.32$, $p < .001$, and lag, $F(6,222) = 61.17$, $p < .001$, were found. Semantic study ($M = .439$) yielded higher target production than graphemic study ($M = .330$), and target production declined as lag increased (see Fig. 2). In addition, a study type by lag interaction was found, $F(6,222) = 2.31$, $p < .05$, indicating a difference in the levels of processing effect for different study–test delays. No other effects were found to be significant, all ps $> .140$.

Forgetting fits. As in our previous studies comparing forgetting on implicit and explicit tasks (see McBride & Dosher, 1997, 1999), power functions were fit to the data in order to estimate rates of decline and characterize the form of forgetting. A comparison of function rates (estimated by model fits) is the appropriate test for evaluating forgetting as suggested by Loftus (1985). Using weighted least-squares methods, data were first fit by a single process power function of the form

$$P(t) = \lambda t^{-\beta}$$

where $P(t)$ is the probability of producing a target at time t, λ is the initial level of encoding, and β is the rate of decline. A full model, where each curve is fit separately, with four λs and four βs (one λ and one β for each condition), fit the data reasonably well with an R^2 of .87.[1] Constraining the model to a common forgetting rate β (five parameters, four λs, and a single β for all conditions), however, did not significantly reduce the goodness of fit ($R^2 = .89$), $F(3,20) = 2.59$, $p > .05$.[2] If the rate of forgetting differed substantially for the various conditions, assuming a single forgetting rate should have significantly reduced the quality of the fit. That it did not indicates that forgetting was similar for all conditions, including implicit and explicit task types.

The fits to the single process power function, however, were not as good as fits to a composite form of the function, as was also shown in previous studies (McBride & Dosher, 1997, 1999). The rapid decline in performance during short delays and the slow decline for longer delays are not easily captured by a single process function. A composite form captures both the early rapid decline as well as the slower decline exhibited for longer delays. This function is of the form

$$P(t) = \max[\lambda t^{-\beta}, \gamma],$$

where β describes the early portion of decline (up to approximately 16 min), while the decline in the later portion (approximately 16 to 45 min) is so shallow that it can be estimated by a constant value, γ. A slow rate of forgetting over hours or days is approximated by the constant γ over the longer retention delays of this study. (See McBride & Dosher, 1997, for a detailed discussion.)

A full 12-parameter composite model fit the data quite well, $R^2 = .96$.[3] A nine-parameter model (with one β for all conditions) did not significantly reduce the goodness of fit to the data, $R^2 = .96$, $F(3,16) = 0.84$, $p > .05$. This result indicates that for this range of retention delays (1 to 45 min), implicit and explicit memory do not show substantial differences in forgetting. The parameter estimates for the nine-parameter, common forgetting rate model can be seen in Table 1. In addition, these functions can be seen graphically in Fig. 3 as lines in the panels for each condition. Table 1 includes estimates of the standard deviations of the parameters of the forgetting model. These standard deviations were estimated using Monte Carlo methods (see McBride & Dosher, 1999) based on the standard errors of the average target production rate at each lag and condition.[4] The esti-

[1] R^2 is the proportion of variance accounted for corrected for the number of estimated parameters. Uncorrected r^2 values were used in the model comparison tests as appropriate.

[2] Test for dropping least-squares model parameters (Wannacott & Wannacott, 1981).

[3] The composite power function fits for both experiments were constrained such that β was estimated for $5 < t < 18$ min. This was necessary due to floor values in certain conditions.

[4] The Monte Carlo method generated new hypothetical sets of data by resampling from a normal distribution with μ = observed average target production rate and standard deviation estimated by the standard error estimated for each average. Twenty sets of resampled values were fit by the forgetting functions, and the variability in the estimated parameters provided an estimate of the variance in the parameter values. See McBride and Dosher (1999) for a discussion.

TABLE 1

Parameter Estimates for a Nine-Parameter Composite Power Function Fit to the Data from Experiment 1

Condition	λ	*SD*	β	*SD*	γ	*SD*
Implicit						
Semantic	0.672	0.025	0.322	0.022	0.276	0.018
Graphemic	0.531	0.024	—	—	0.222	0.011
Explicit						
Semantic	0.710	0.028	—	—	0.370	0.017
Graphemic	0.516	0.028	—	—	0.241	0.018

Note. Standard deviations were estimated by resampling methods.

mated 95% confidence interval for the rate of forgetting β (0.274, 0.370) is modest. The largest difference in predicted values for βs of 0.294 and 0.385 average 6% at the largest relevant retention delay of approximately 16 min, which is within the estimated confidence intervals for the data points. The estimated standard deviations for the β parameters in the model allow an estimate of the power of certain tests of the forgetting model, which assist in evaluation of the fits of this model to our data. For example, in a test for a difference between two βs (directly related to the nested *F* test on the models), one for explicit and one for implicit performance, a power of .90 is associated with a difference in βs of 0.13. In the range of the observed β for the performance levels in this experiment, this β difference would correspond to a maxi-

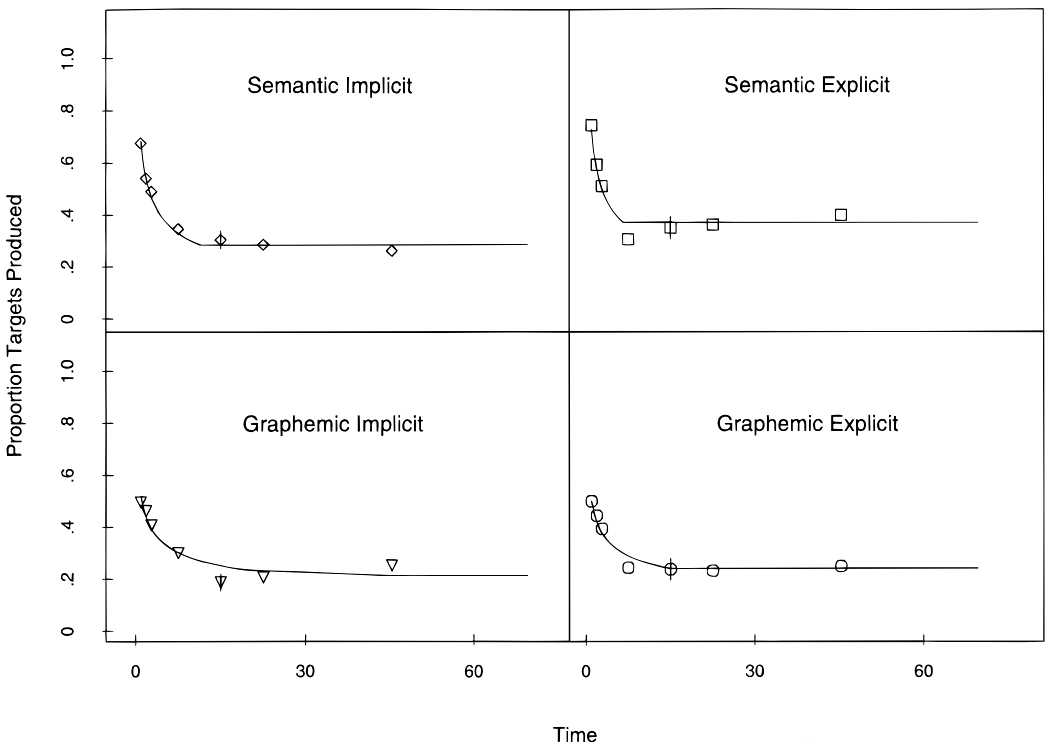

FIG. 3. Experiment 1 data plotted with fitted curves from the 1 β (1 β for all conditions) composite power function. Each study and task condition is shown in a separate panel. Standard errors of the means are shown on representative data points (80-item lag, 15.1-min delay) in each panel.

mum predicted difference in target production of 8% at a delay of 16 min, or a predicted difference in target production in the mid-range delays for the fast forgetting portion of about 4%.

Implicit tasks are not expected to result in a levels of processing difference, and in the cases where a levels of processing effect is found, it has been suggested that explicit contamination may have been the cause (e.g., Hamann & Squire, 1996). In the ANOVA results of Experiment 1, an overall study type main effect was found that was not qualified by a study type by test type interaction. This result contrasts with results found for stem completion in similar studies (McBride & Dosher, 1997, 1999); however, stem completion and fragment completion tasks may differ in a number of ways. Typically, fragment completion tasks are more difficult for subjects to perform and result in lower unstudied baseline completion rates. McBride and Dosher (1997) reported average reaction times of 1.3 to 1.9 s for completion of word stems, while Weldon (1993) reported median reaction times of 3.0 to 5.0 s for completion of word fragments. In Experiment 1, average reaction times for target production were 2.831 and 2.984 s for implicit and explicit tasks, respectively.[5] These values are comparable to values reported by Weldon (1993) for fragment completion. Due to the increased difficulty of fragment completion, subjects may be more likely to engage in explicit retrieval to perform fragment completion tasks than they would for stem completion tasks. In the previous study, McBride and Dosher (1997) distinguished implicit and explicit forms of stem completion with evidence of longer reaction times for the explicit task than for the implicit task. Unfortunately, this was not possible in the current study because reaction times for the fragment completion tasks were highly variable. Although we believe that the explicit task instructions invoke substantially more explicit processing than implicit instructions, it is nonetheless possible that the implicit task in Experiment 1 may have been contaminated by explicit retrieval, which may have resulted in more similar forgetting rates for the two types of memory. Therefore, it was important to examine forgetting rates for "process pure" estimates of implicit and explicit memory. Experiment 2 addressed this issue by estimating conscious and automatic memory processes.

[5] Due to large standard errors of the means, these results should be interpreted with caution.

EXPERIMENT 2

Experiment 2 applied a process dissociation procedure to the design of Experiment 1. Inclusion and exclusion fragment completion tasks were given in place of implicit and explicit instructions. For the inclusion task, subjects were instructed to complete fragments with a word they had studied, or if they could not think of an item they studied that fit the fragment, to complete the fragment with any word they could. For the exclusion task, the instructions were to complete the fragment with an item that they had not studied in the experiment (i.e., a new item). For both tasks, subjects were given the option of responding with XXX if they could not think of an item that fit the instructions. Subjects again studied items under semantic and graphemic instructions with study–test lags of 5, 10, 15, 40, 80, 120, and 240 items. Through the use of Jacoby's (1991) process dissociation procedure, conscious and automatic memory processes were estimated for each lag using multinomial process tree models, allowing a comparison of forgetting for the estimates of the two memory processes.

Process Dissociation Procedure

Jacoby's (1991) process dissociation procedure has been used to compare conscious and automatic forms of memory with a number of manipulations. The procedure relies on task performance for two different kinds of task instructions. On an inclusion task, subjects are asked to complete the task with either a studied item or an alternate item. In this way, subjects may respond with a studied item through either a conscious memory process (C) or an automatic memory process (A). The second task is called an exclusion task because subjects are instructed to exclude studied items. Instead, they are asked to respond with an item they did not study. For this task, subjects can respond with a studied item only through an automatic process, since they are asked to exclude studied items they consciously recollect. The following equations then can describe inclusion and exclusion task performance,

$$P(\text{target, inclusion}) = C + (1 - C)A$$

and

$$P(\text{target, exclusion}) = (1 - C)A$$

where P(target) is the probability of producing a studied item on each task. From these equations, the probabilities of C and A can be estimated, respectively, by

$$C = P(\text{target, inclusion}) - P(\text{target, exclusion})$$

and

$$A = P(\text{target, exclusion})/(1 - C).$$

The process dissociation procedure, however, has been criticized for the assumption that C and A are independent on any given trial (see Curran & Hintzman, 1995; 1997; Hintzman & Curran, 1997; and for rebuttal see Jacoby, Begg, & Toth, 1997; Jacoby & Shrout, 1997).[6] Curran and Hintzman (1995) have shown that correlations between C and A are found in some cases. In addition, Jacoby's (1991) procedure has been faulted for not including any estimation or correction of guessing processes (Buchner, Erdfelder, & Vaterrodt-Plünnecke, 1995).

Conscious and automatic memory processes are not directly equivalent to explicit and implicit memory. Instead, it is assumed that conscious/explicit and automatic/implicit are partially overlapping concepts, and they do show similar patterns of results (see the General Discussion for further discussion of this point). However, several processes most likely contribute to performance on implicit and explicit tasks. Therefore, task performance and process estimates may not be directly comparable.

Process Tree Models

Multinomial process tree models (Batchelder & Riefer, 1990, 1999; Riefer & Batchelder, 1988) have been used recently as an extension of Jacoby's (1991) procedure. For example, Buchner et al. (1995) estimated latent memory processes using multinomial models fit to data from process dissociation tasks in recognition. In addition, McBride and Dosher (1999) used multinomial models to estimate forgetting rates for conscious and automatic memory processes from stem completion tasks estimated with a process dissociation procedure. They found no difference in forgetting rate for conscious and automatic memory processes over a range of delays from 1 to 60 min.

The use of multinomial models allows for estimation of guessing parameters as well as internal correction for baseline in some model forms. Therefore, two multinomial process tree models that have been used in previous research with a stem completion task (McBride & Dosher, 1999) were fit to the response frequency data from Experiment 2. The first model, the non-high-threshold model, is based directly on Jacoby, Toth, and Yonelinas' (1993) equations for stem completion. In this model, conscious (C) and automatic (A) memory are assumed to be independent. Separate C and A parameters are estimated for each study by lag condition. Therefore, C and A memory for semantic and graphemic study can be compared, and the decline in the estimated levels of conscious and automatic memory can be measured over retention delays. The C and A parameters are estimated using all category response frequencies (target item, alternate item, or XXX, no response) from the inclusion and exclusion tasks. This model is shown in Fig. 4. A separate tree represented each study/test condition. For inclusion and exclusion trials, C and A parameters were estimated in separate trees for semantic, graphemic, and unstudied study conditions. The same C and A parameters were used in both inclusion and exclusion trees. A different model was fit to frequency data for each lag. The non-high-threshold model also estimates the probability of generating an alternate word (W) in the absence of both C and A for inclusion and exclusion tasks.

The second model is a high-threshold model that is similar to one used by Buchner et al. (1995) for a recognition task. This model also assumes independence between conscious and automatic forms of memory, but it incorporates

[6] The independence assumption of the process dissociation procedure between C and A does not necessarily imply separable memory systems. Independence is assumed on a trial by trial basis, which could be subsumed by a single memory system.

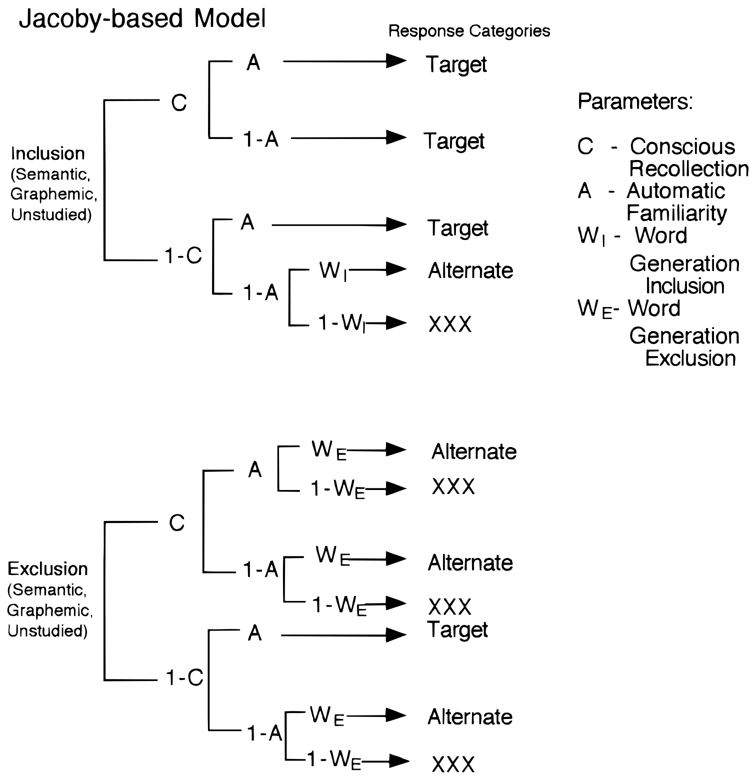

FIG. 4. A multinomial process tree model based on Jacoby et al.'s (1993) process dissociation procedure equations (non-high-threshold model). An additional word generation parameter has been included. Separate trees are included for each task type with the presence or absence of *C* and *A* processes leading to one of the three response categories: target, alternate, or no response (xxx).

guessing into all conditions for the two test types (inclusion and exclusion). *C* and *A* are estimated for each study instruction by lag condition. The high-threshold character of the model is shown in the estimation of parameters based on responses to unstudied items. Both *C* and *A* are assumed to be absent (0) for unstudied stimuli. Word generation (*W*) and guessing (*G*) parameters accommodate the baseline target production for unstudied items, and the same guessing factors operate in other conditions as well. Hence, baseline values are removed from estimates of *C* and *A*. This model is shown in Fig. 5. Like the non-high-threshold model, a separate tree represents processing for each study/test condition. However, in the high-threshold model, no *C* or *A* parameters are estimated for the unstudied conditions. Instead, guessing accounts for the production of target items when these items were not studied.

The two models described above were fit to performance data from the fragment completion tasks (inclusion and exclusion instructions). Both models estimated conscious and automatic memory processes for conditions involving semantic and graphemic study instructions and the seven study–test lags. Power functions were then fit to these estimates to compare forgetting rates for conscious and automatic memory processes used in the tasks.

Method

Participants. Fifty-five UC Irvine students voluntarily participated in Experiment 2 in exchange for course credit. All subjects had pretest typing speeds of 25 words per minute or higher.

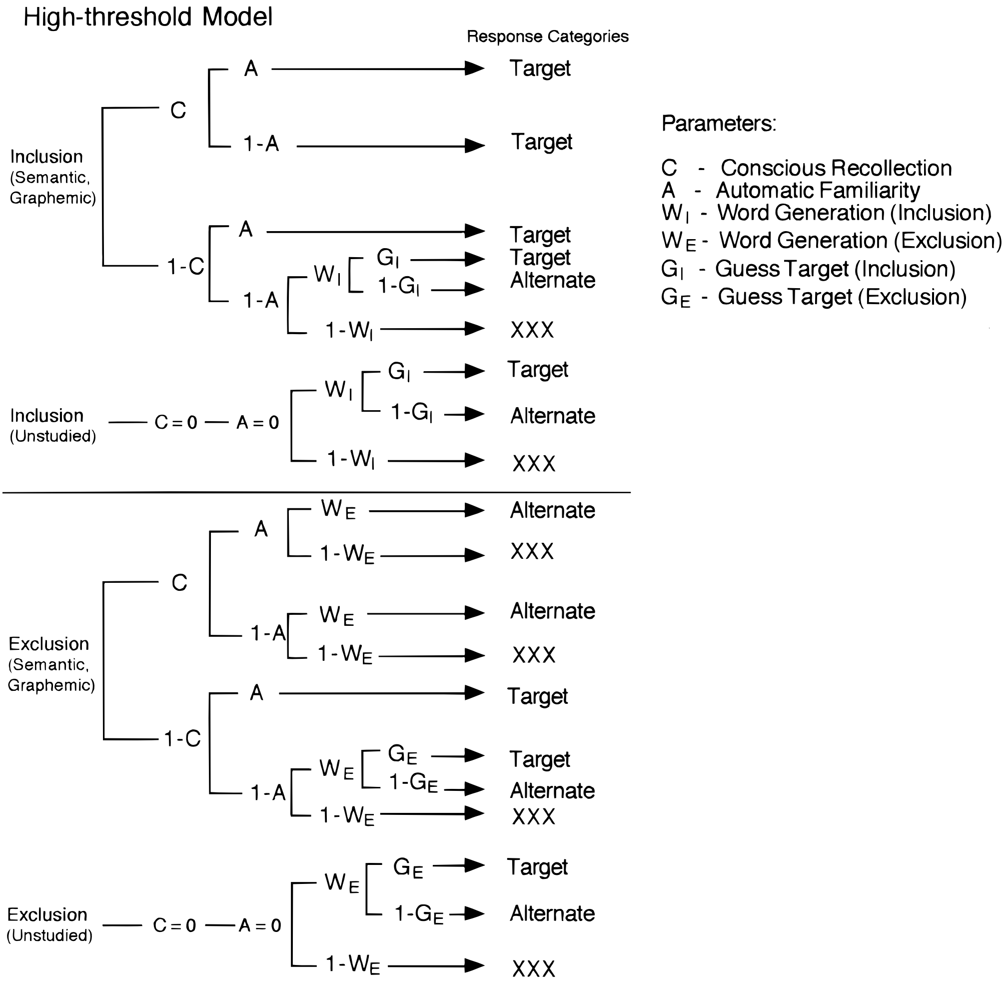

FIG. 5. A multinomial process tree model that incorporates guessing for stem completion based on Buchner et al.'s (1995) model (high-threshold model). Separate trees are shown for each task, including separate trees for unstudied conditions.

Twenty-seven subjects received inclusion instructions, while 28 received exclusion instructions. All subjects were native English speakers.

Materials and design. The same 160-word target list used in Experiment 1 was used in Experiment 2. These items and their fragments are listed in Appendix A. Again, all fragments had at least three possible solutions. The same list of filler words was used for vowel counting trials.

Trial order and item assignment were conducted as in Experiment 1. Of the 140 target items chosen for study, 70 were randomly assigned to the semantic study instruction and 70 were randomly assigned to the graphemic study condition. These items were then randomly assigned (10 of each study type for each lag) to each of the seven study–test "trial" lags (5, 10, 15, 40, 80, 120, and 240 trials). As in Experiment 1, trials included a target study item and vowel counting filler pair, two vowel counting filler items, or a fragment test trial. Study and test positions were chosen randomly such that the correct number of trials intervened between the study and test for each studied target item. Twenty fragments for unstudied target items were also placed in the trial sequence. For each subject, all test trials were given with either inclusion or exclusion instructions.

Procedure. In Experiment 2, subjects completed 320 total trials. The trial sequence was similar to that of Experiment 1. A "!" or a "#" signature preceded each target study trial for 710 ms to indicate semantic and graphemic study instructions, respectively. Then the target word appeared with the signature for 2.5 s. The experiment continued when a response was recorded (1–7 rating for pleasantness or number of vowels in the word). Each target item was succeeded by a vowel counting filler item to keep study and test trial timing consistent, as in Experiment 1.

Subjects assigned to the inclusion condition were instructed to look at each fragment and first try to determine if a previously presented item could complete the fragment. If they remembered an item, they were to type in the entire word. If they could not remember an item that fit the fragment, subjects were to type in the first word they could think of that completed the fragment or "xxx" if they could not solve the fragment with any word. For exclusion instructions, subjects were asked to look at each fragment and attempt to solve it with an item they had not seen before in the experiment. A strategy was suggested, to first attempt to remember an old item that solved the fragment and then to discard that item and think of another solution. If they could not think of an unstudied solution, subjects were instructed to respond with "xxx". These instructions are similar to instructions used by Jacoby et al. (1993) in their process dissociation procedure study of stem completion.

Timing estimates. Timing estimates were conducted as in Experiment 1 to determine study–test time delays. Time lags for Experiment 2 were 0.95, 1.90, 2.84, 7.58, 15.17, 22.75, and 45.50 min. Timing was similar for subjects with inclusion (0.1889 min/trial) and exclusion (0.1903 min/trial) instructions.

Results and Discussion

Target production data for each lag and study/test condition can be seen in Fig. 6. Figure 6 shows performance over time, but the change in performance should not be interpreted as for-

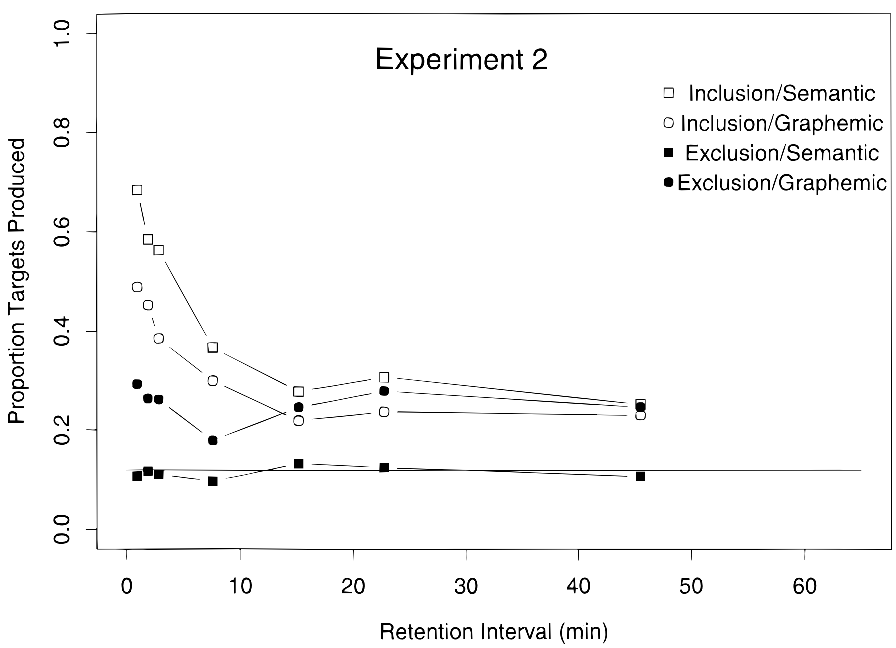

FIG. 6. Proportion correct data from Experiment 2 for inclusion and exclusion fragment completion tasks as a function of test delay. Each line represents a different study/test condition.

TABLE 2

Parameter Estimates from the Non-high-Threshold Multinomial Model for Experiment 2

Lag	C_s	C_g	A_s	A_g	W_i	W_e	$G^2(4)$
5	.578	.196	.254	.364	.644	.718	8.72
10	.468	.188	.221	.325	.642	.699	12.67
15	.452	.124	.202	.299	.643	.720	6.84
40	.270	.121	.132	.203	.643	.709	6.86
80	.145	.001	.155	.232	.623	.702	7.02
120	.182	.001	.153	.258	.663	.709	15.13*
240	.145	.001	.125	.238	.635	.722	4.24

Note. $C_u = 0.021$; $A_u = 0.111$.
*$p < .005$.

getting due to the nature of the inclusion and exclusion tasks. These data were analyzed by an ANOVA of retention lag, study type, and test type. Main effects of test type, $F(1,53) = 144.92$, $p < .001$, and lag, $F(6,318) = 29.10$, $p < .001$, were found. The effect of test type indicates higher target production for inclusion trials than for exclusion trials, while the effect of lag indicates that overall performance tended to decline as study–test delay increased. A significant interaction of test and lag was also found, $F(6,318) = 24.80$, $p < .001$, indicating that target production differed for inclusion and exclusion trials based on lag.

No main effect of study type was found, $F(1,53) = 2.35$, $p > .05$, but study type did interact with test type, $F(1,53) = 113.31$, $p < .001$, indicating that differences in target production for semantic and graphemic study depended on the test instruction given. No interaction of study type and lag was found, $F(6,318) = 1.11$, $p > .05$. A three-way interaction of study type, test type, and lag, however, was evident, $F(6,318) = 3.40$, $p < .005$.

Model fits. Response frequency data for the three response categories were fit by the two multinomial process tree models described above. Response frequencies for all conditions are given in Appendix B. A separate multinomial model was fit for each lag.[7] The non-high-threshold (Jacoby-based) model estimated conscious (C) and automatic (A) memory parameters for semantic (C_s and A_s) and graphemic (C_g and A_g) study items and for unstudied items (C_u and A_u), as well as word production parameters for inclusion and exclusion tasks (W_i and W_e). Parameter estimates can be seen in Table 2 for this model. Data points are shown in Fig. 7. Predicted frequencies of the model are listed in Appendix C. The average estimate of conscious memory for unstudied items, C_u, was .021, while the estimate of automatic familiarity for unstudied items was .111. Therefore, the baseline is estimated to reflect almost entirely automatic familiarity. These estimates of conscious and automatic memory following semantic and graphemic study are consistent with standard claims about the effects of levels of processing. Estimated values of C_s exceed those of C_g at all lags. Estimated values of A_s are actually lower than those of A_g for all lags. The power for each of the multinomial model fits was estimated at higher than .99 in all cases (for $\alpha = .05$). Effect sizes ranged from 0.04 to 0.08. Sample 95% confidence intervals around the estimates are shown as twigs on a few representative data points in Fig. 7.

The high-threshold (guessing-elaborated) model estimated C_s, C_g, A_s, A_g, W_i, and W_e parameters, as well as guessing probabilities for each task type (G_i and G_e). These estimates can be seen in Table 3 for the high-threshold model. These values are shown as data points in Fig. 8.

[7] The data were fit one lag at a time because of size constraints in the multinomial estimation program of Hu (1991). The same unstudied trial data were included in the fits at every lag. We used this program rather than a standard minimization package because it provides confidence interval and statistical testing functions.

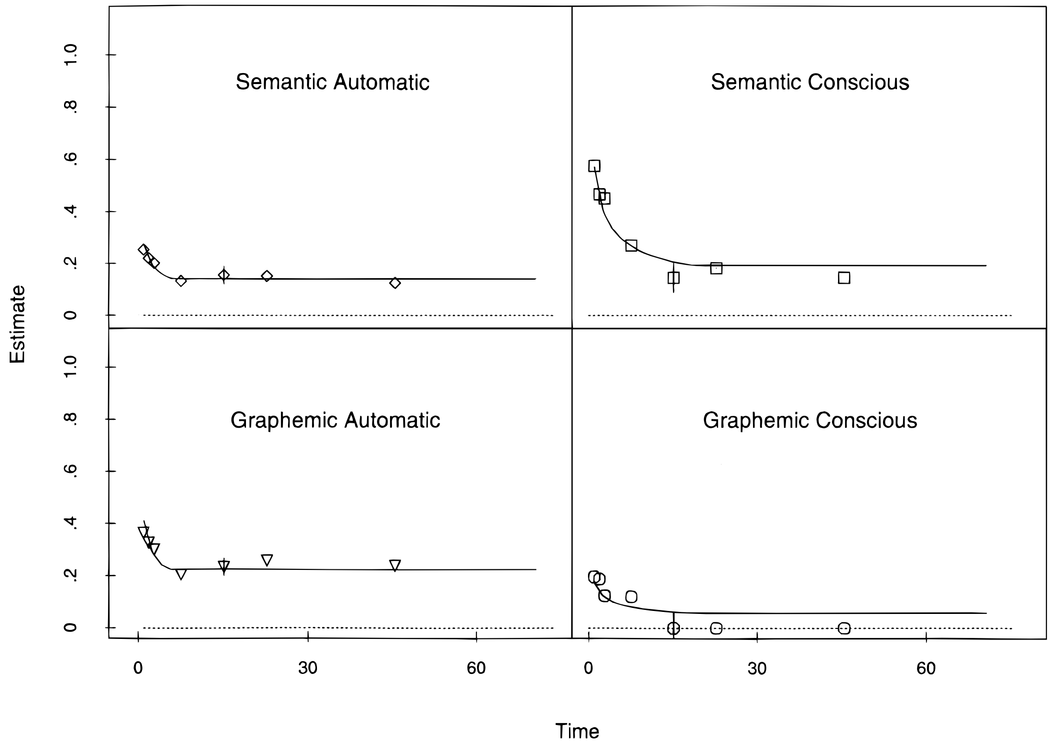

FIG. 7. Model estimates of the non-high-threshold model for *C* and *A* for Experiment 2. For clarity, estimates for each study/test condition are displayed in a separate panel. Lines overlaid represent fitted values of the single β composite power function. Ninety-five percent confidence intervals (as calculated by the Hu, 1991, program) are shown on representative points (80-item lag, 15.2-min delay) in each panel.

Predicted frequencies of the model are listed in Appendix C. This model incorporates baseline levels into guessing and word generation parameters. Hence, estimates of conscious and automatic processing incorporate a correction for baseline. As in the low-threshold model, $C_s > C_g$ at all lags and $A_s < A_g$ at all lags.

Both models appear to fit the data well. All G^2 values (analogous to χ^2 for the model fit) are low and can be seen for each lag in Tables 2 and 3. As described above, *C* estimates show a levels of processing effect for conscious memory, with semantic study resulting in higher estimates than graphemic study. Unlike Experiment 1, the

TABLE 3

Parameter Estimates from the High-Threshold Multinomial Model for Experiment 2

Lag	C_s	C_g	A_s	A_g	W_i	W_e	G_i	G_e	$G^2(2)$
5	.567	.184	.158	.282	.690	.742	.188	.144	11.12*
10	.453	.171	.122	.238	.689	.726	.189	.147	15.26*
15	.439	.109	.101	.208	.690	.746	.188	.144	8.43
40	.252	.103	.024	.102	.690	.738	.188	.146	7.84
80	.134	.001	.046	.129	.670	.735	.186	.154	8.14
120	.174	.001	.043	.158	.704	.740	.175	.154	16.15*
210	.133	.001	.013	.135	.681	.752	.185	.150	4.78

$*p < .005$.

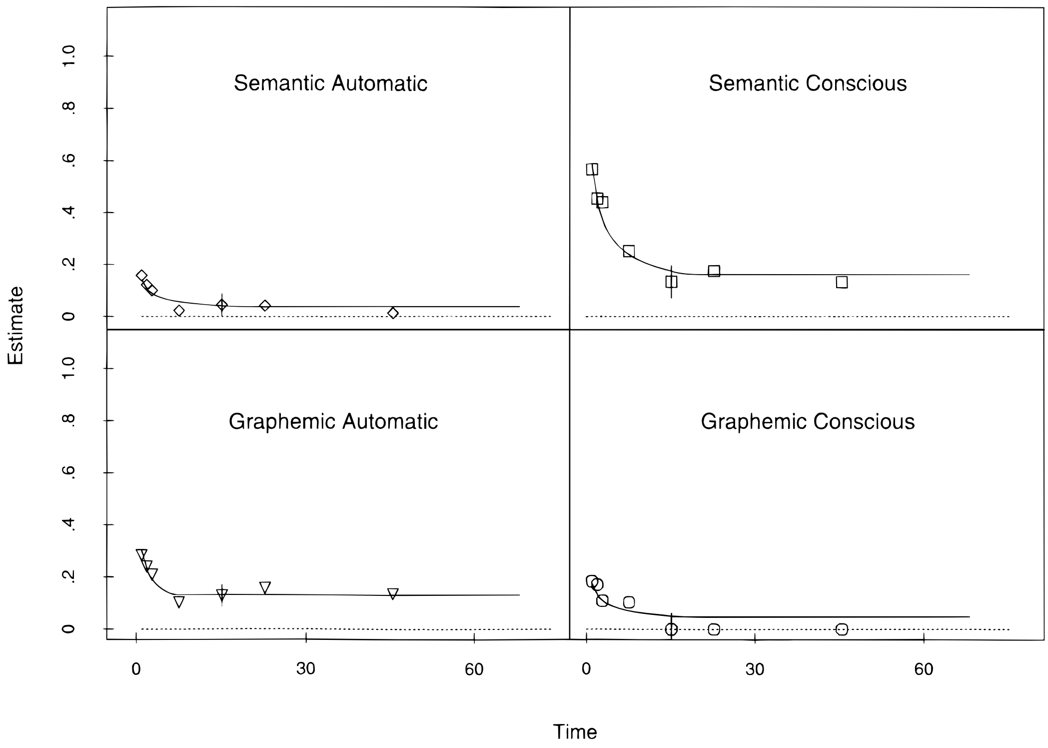

FIG. 8. Model estimates of the high-threshold model for *C* and *A* for Experiment 2. Estimates for each study/test condition are shown in a separate panel. Lines overlaid represent fitted values of the single β composite power function. Ninety-five percent confidence intervals (as calculated by the Hu, 1991, program) are shown on representative points (80-item lag, 15.2-min delay) in each panel.

A estimates did not show a semantic study advantage. Instead, the *A* estimates are greater for the graphemic study condition. These results are consistent in both the non-high- and high-threshold models.

A third multinomial model was also fit to data for Experiment 2, as a comparison to the two independence models described above. This model is based on a generate-source view of fragment generation and does not assume independence between these two processes. This model estimated the two processes of generating a target (*G*) and matching the source for that target as studied (*S*), which are assumed to be comparable to a certain degree to the *A* and *C* processes in the previous two models (see Appendix D and McBride & Dosher (1999) for a more thorough discussion of the source model). The source model generally fit the data as well as the independence models. A comparison of G^2 values showed that the source model fit was slightly better than the fit of the high-threshold model. Therefore, the quality of the fit does not depend on an assumption of independence between conscious and automatic memory processes. However, this model comparison is not meant to indicate that the G^2 value is the preferable method of model distinction, and it should not be interpreted as a validation of the non-high-threshold model described above. Predicted frequencies from the source model are listed in Appendix C. A full discussion of the source model is given in Appendix D.

Forgetting fits. As in Experiment 1, data were fit with power functions to estimate rates of forgetting for conscious and automatic memory components. However, for Experiment 2, the power functions were fit to *C* and *A* estimates from the multinomial models.

TABLE 4

Parameter Estimates for a Nine-Parameter Composite Power Function Fit to the Non-high-Threshold Model Data from Experiment 2

Condition	λ	*SD*	β	*SD*	γ	*SD*
Conscious						
Semantic	0.574	0.021	0.376	0.023	0.194	0.011
Graphemic	0.175	0.025	—	—	0.059	0.007
Automatic						
Semantic	0.274	0.020	—	—	0.141	0.010
Graphemic	0.410	0.015	—	—	0.224	0.012

Note. Standard deviations were estimated by resampling methods.

As in Experiment 1, single process power function models were considered, but they were rejected in favor of the composite power function. Composite power function fits were conducted in order to capture both the fast and the slow declining portions of the data. For the non-high-threshold model, a full 12-parameter function (separate λ, β, and γ for each condition) fit the data quite well with an $R^2 = .94$. A constrained 9-parameter function (one β for all conditions) fit the data nearly as well, $R^2 = .92$, $F(3,16) = 3.16$, $p > .05$. This indicates similar rates of forgetting for both conscious and automatic forms of memory. The high-threshold model estimates showed similar results. A 12-parameter fit ($R^2 = .93$) was statistically equivalent to a 9-parameter fit ($R^2 = .93$), $F(3,16) = 1.18$, $p > .05$. The estimates for the 9-parameter fits for the non-high- and high-threshold multinomial models are given in Tables 4 and 5, respectively. In addition, the composite power functions with estimated λ, β, and γ parameters are shown graphically in Figs. 7 and 8 with model estimates of *C* and *A* indicated from the non-high- and high-threshold models, respectively.

Tables 4 and 5 also include standard deviation estimates for the fitted parameters of the forgetting model. These standard deviations were derived by Monte Carlo resampling based on the variance estimates provided by the MBT program (Hu, 1991). For the Jacoby-based non-high threshold model, the confidence interval for the forgetting rate parameter β (0.329– 0.425) is relatively narrow. These values are best viewed within the context of their impact on predicted values. At the longest applicable *t* of the fast forgetting portion (which generates the largest difference), the predicted values using $\beta = 0.329$ and $\beta = 0.425$ differ by an average of 4%, well within the size of the 95% confidence intervals on the values of *C* and *A*. For the high-threshold model, the 95% confidence interval on β (0.370–0.521) is somewhat larger; however, the average impact of this confidence interval on the predicted values is still only 4%. Again, this is

TABLE 5

Parameter Estimates for a Nine-Parameter Composite Power Function Fit to the High-Threshold Model Data from Experiment 2

Condition	λ	*SD*	β	*SD*	γ	*SD*
Conscious						
Semantic	0.587	0.034	0.446	0.036	0.162	0.012
Graphemic	0.174	0.025	—	—	0.048	0.008
Automatic						
Semantic	0.140	0.008	—	—	0.039	0.007
Graphemic	0.300	0.023	—	—	0.132	0.008

Note. Standard deviations were estimated by resampling methods.

well within the confidence intervals on C or A. As described for Experiment 1, the estimated standard deviations for the β parameters in the model allow an estimate of the power of certain tests of the forgetting model, which assist in evaluation of the fits of this model to our data. For the non-high-threshold model, the test for a difference between two βs (directly related to the nested F test on the models), one for conscious and one for automatic processes a power of .90 is associated with a difference in βs of 0.13. In the range of the observed β for the performance levels in this experiment, this β difference would correspond to a maximum predicted difference in target production of about 6% at a delay of 16 min, or a predicted difference in target production in the mid-range delays for the fast forgetting portion of about 3%. In the equivalent test for the high-threshold model a power of .90 is associated with a difference in βs of 0.15. The β difference for the high-threshold model would correspond to a maximum predicted difference in target production of about 4% at a delay of 16 min, or a predicted difference in target production in the midrange delays for the fast forgetting portion of about 2–3%.

Although the estimated forgetting rates for the four conditions do not differ significantly, the transition points between the fast- and slow-forgetting portions of the performance functions do differ somewhat over conditions. This is primarily due to the difference in initial values (λ) for the four conditions in relation to the levels of the slow-forgetting portion (γ). The semantic-conscious condition, for example, has a relatively high initial value λ in relation to γ, and, therefore, performance takes longer to reach that level than in other conditions where the initial value is very low. However, equal rates in the complex power function for forgetting are the model-appropriate equivalent to tests developed for exponential forgetting (Loftus, 1985).[8] This point will be elaborated further below.

The source model fits showed similar results (see Appendix D for details), indicating that the conclusions do not depend on an assumption of independence between C and A. A 4 β composite power function fit the source model estimates well. The quality of the fit was not reduced by a power function with two β parameters (one β for the S_s process and one β for the other three processes). The only difference between the source model and the independence models described above was evidence of a slower rate of decline for the S_s process. Estimated parameters of the source model appear in Table 6. Table 7 contains forgetting model parameters for this model.

These results are indicative of quite similar rates of forgetting for estimates of conscious and automatic memory from the multinomial models tested. The results of Experiment 2 for fragment completion tasks were consistent with results reported by McBride and Dosher (1997,

[8] These apparent differences in the point of transition between the fast forgetting to slow forgetting regions were not evident in previous studies estimating forgetting for conscious and automatic memory in word-stem completion (McBride & Dosher, 1997, 1999). In those studies, the points of transition were relatively similar in all conditions.

TABLE 6

Parameter Estimates from the Source Multinomial Model for Experiment 2

Lag	S_s	S_g	G_s	G_g	G_u	S'	W_i	W_e	$G^2(4)$
5	.844	.401	.685	.489	.119	.000[a]	.644	.718	9.82
10	.799	.415	.585	.452	.119	.000[a]	.642	.699	13.77
15	.803	.231	.562	.385	.122	.050	.643	.728	7.85
40	.736	.404	.366	.300	.125	.010	.643	.727	7.63
80	.519	.001	.277	.233	.129	.148	.623	.730	7.24
120	.591	.001	.307	.258	.130	.158	.663	.737	15.14*
210	.574	.001	.252	.238	.130	.163	.635	.750	4.17

[a] Estimated at 0.0001.

*$p < .005$.

TABLE 7

Parameter Estimates for a 10-Parameter Composite Power Function Fit to the Source Model Data from Experiment 2

Condition	λ	*SD*	β	*SD*	γ	*SD*
Source						
Semantic	0.856	0.016	0.108	0.009	0.626	0.017
Graphemic	0.434	0.039	0.303	0.018	0.181	0.014
Generate target						
Semantic	0.693	0.024	0.303	0.018	0.289	0.011
Graphemic	0.518	0.016	0.303	0.018	0.243	0.014

Note. Standard deviations were estimated by resampling methods.

1999) for stem completion tasks. No substantial difference in rate or form of forgetting is evident for conscious and automatic forms of memory.

GENERAL DISCUSSION

Levels of Processing

A levels of processing effect was found in Experiment 1. For both implicit and explicit fragment completion, semantic study resulted in higher performance than graphemic study. This result, although contrary to claims that implicit memory tasks are not affected by levels of processing manipulations, is not unusual. Past studies (Brown & Mitchell, 1994; Challis & Brodbeck, 1992) have shown that although levels of processing effects are not always found to be significant for implicit tasks, they are often present nonetheless. This result has been found for both stem and fragment completion tasks, as well as for other common implicit memory tasks. The results in the current study for Experiment 1 are consistent with these findings. In an attempt to explain levels of processing effects in implicit tasks, some researchers have argued that these results may be due to explicit retrieval occurring during the implicit tasks. Therefore, it is important to also examine "process pure" estimates of memory, rather than to base conclusions about the different types of memory solely on task performance.

To date, few studies have examined fragment completion performance using the process dissociation procedure (see Russo, Cullis, & Parkin, 1998, for one study). Use of the process dissociation procedure required use of multiple-solution fragments, which may have changed the nature of the task slightly. In addition, accurate measure of forgetting required a procedure that differed from most past studies of fragment completion. In order to measure performance at several retention intervals, a continuous trial sequence was used with study and test trials embedded within filler item trials. This procedure deviates from the usual study/test portion procedure used by many researchers. However, this procedure was used in our past studies (McBride & Dosher, 1997, 1999) examining stem completion tasks where results were consistent with previous findings with these tasks. Overall, the fragment completion results in the current study are consistent with findings from past studies using the current continuous trial procedure and studies using the more common study/test portion procedure.

Comparison of Forgetting

Experiment 1 evaluated forgetting for explicit and implicit versions of a fragment completion task. Experiment 2 compared forgetting rates for conscious and automatic memory estimates in fragment completion tasks using the process dissociation procedure (Jacoby, 1991) and multinomial models of the tasks (Batchelder & Riefer, 1990, 1999; Riefer & Batchelder, 1988). For target production measures of forgetting in Experiment 1 and for latent memory process estimates in Experiment 2, the form of forgetting included an initial period of rapid decline for retention intervals less than 5–18 min, and slower forgetting for longer retention intervals. This form of forgetting is consistent with past results. In the current study, the best fit function was a composite power function where performance at short retention intervals was characterized by a rapid rate of forgetting and performance at longer delays was characterized by a much slower rate of decay (fit by a constant value in the present experiments). This two-rate form of forgetting was also found for memory performance from stem completion tasks (McBride & Dosher, 1997) and for conscious and automatic memory estimates from stem completion tasks (McBride & Dosher, 1999). This form of forgetting was also reported by Sloman et al. (1988) for fragment completion performance. The data of Sloman et al. are shown in Fig. 1 and also display a rapid decline in performance followed by a much slower decline for longer delays. The form of forgetting seen in the current experiments is similar to that seen in past research.

These results do not depend on the assumption of independence that characterizes both the non-high- and high-threshold models. A source model that assumes dependence between memory processes fit the Experiment 2 data as well as the independence models. Further, the forgetting fit results for the source model were similar to results for the other two models and do not indicate substantial forgetting differences between the memory processes estimated. The source model only differed from the other models by displaying greater variance in the parameter estimates from the multinomial model fits and indicating a slower rate of decline for the source match process under graphemic study. See Appendix D for more information about the source model and its fits. A comparison of the predicted frequency values for each model (see Appendix C) shows that values differed by an average of 0.02 across models, indicating that the models are fitting the data in a very similar manner.

Composite power function fits to the target production data of Experiment 1 showed similar rates of forgetting for implicit and explicit task instructions over the range of retention delays from 1 to 45 min. Composite power function fits to estimates from the two models (both non-high-threshold and high-threshold models) also showed similar rates of forgetting for conscious and automatic memory processes over the same delays. The results of both experiments were consistent with results of similar rates of forgetting for implicit and explicit stem completion (McBride & Dosher, 1997) and for conscious and automatic memory tested by stem completion tasks (McBride & Dosher, 1999) over a similar range of delays. The current results are not supportive of claims that implicit memory as tested by fragment completion tasks has a substantially slower rate of forgetting than explicit memory.

Due to claims that implicit and explicit memory tasks may in some cases involve an overlapping of the two kinds of memory processes (Hamann & Squire, 1996), it was important to compare implicit/explicit dissociations with "process pure" estimates of each memory type. In Experiment 1, ANOVA results indicated the presence of levels of processing effects for both implicit and explicit memory tasks. As indicated above, implicit tasks are believed to be insensitive to differences in level of processing, and when they do show these effects, researchers have claimed the effects are due to contamination of the task by explicit retrieval. Therefore, the similarity of forgetting rates found in Experiment 1 may have been due to this type of contamination. The results of Experiment 2, however, do not support this explanation of the results. Experiment 2 examined "process pure" estimates of conscious and automatic memory, and results consistent with Experiment 1 were found: No forgetting rate differences were observed when estimates of conscious and automatic memory were compared. In addition, no levels of processing effect was found for *A* estimates from either multinomial model. In fact, the *A* estimates for the graphemic study condition appear to be higher than the *A* estimates for the semantic condition. This result is similar to findings by Russo et al. (1998). They found higher *A* estimates in a process dissociation procedure with fragment completion after graphemic study than after semantic study. The levels of processing results from Experiment 2 are consistent with the majority of the findings in this area and are supportive of theoretical ideas regarding implicit memory as indicated above.

Results from the present study relate to retention delays of 45 min or less and, therefore, do not measure forgetting rates over longer retention intervals (e.g., days, weeks). In fact, performance in most conditions was still above baseline levels, and it is not clear from the current study the rate at which forgetting would occur during longer retention intervals. Different forms of forgetting in explicit and implicit memory performance have been reported by researchers using a word fragment completion task for intervals up to 2 weeks (e.g., Snodgrass & Surprenant, 1989). These studies compared performance on a fragment completion task to performance on recognition memory tasks. These tasks, however, differ in their demands and thus may not provide as clean a measure for the comparison of implicit and explicit forgetting rates as the fragment completion and fragment cued recall tasks incorporated in the present study.

Further study of longer delays may prove useful. However, we feel that such studies face special challenges. For example, Experiment 1 measured fragment completion from levels near the top of the range at 75% (lag 5, semantic study) to an average of about 25%, where baseline (unstudied) is 11%. This represents 78% of the total possible range of forgetting. Evaluating forgetting rates over the remaining 14% to baseline presents statistical challenges as well as stimulus selection issues. Nonetheless, future studies may extend the current results to longer forgetting intervals.

The model fitting technique applied in the current study is analogous to the technique proposed by Loftus (1985) for exponential functions. Power functions that directly estimate the forgetting rates were compared in the current experiments. This technique does not require or rely upon a statistical interaction effect between delay time and type of task. For each full model (444), separate dual-process power functions were fit to the performance data for each condition. A separate forgetting rate (β) was estimated for each of the four conditions in the experiments. The nested models that held each condition to a single β (414 model) were compared to the appropriate full model to determine if the nested model fit the data equally (statistically) well. Using this method, the full functions were compared, rather than performance at various delays. Therefore, the model fitting technique described above is not affected by issues of contamination from differing initial levels of performance (Loftus, 1985).

Explicit/Implicit Memory and Conscious/Automatic Processes

It has been argued that conscious and automatic memory processes are not completely equivalent to explicit and implicit memory processes (Graf & Komatsu, 1994; Richardson-Klavehn & Gardiner, 1995). More specifically, a distinction has been proposed between conscious memory and explicit attempts of retrieval. However, in past studies (Jacoby et al., 1993; Toth et al., 1994) it has been shown that conscious and automatic estimates of memory provide patterns of results that closely follow patterns found for explicit and implicit memory. For example, study manipulations such as semantic/graphemic or read/generate produce the same dissociations for explicit/implicit task performance and conscious/automatic estimates. In addition, our past studies have shown strong similarities in forgetting for explicit/implicit performance and conscious/automatic estimates. In one study (McBride & Dosher, 1997), explicit and implicit memory measured by stem completion performance showed dual process forgetting with a single rate of decline. A second study (McBride & Dosher, 1999) showed this same dual process forgetting with one forgetting rate for conscious and automatic memory processes estimated from stem completion performance. These results show that the relationship between conscious and automatic memory and explicit and implicit memory must be strong.

Experiment 1 directly compared implicit and explicit memory for fragment completion. No forgetting rate differences were found for these tasks. Experiment 2 compared conscious and automatic memory estimates from the same tasks and found similar results. Therefore, in as much as the two dimensions of memory are related, these results are inconsistent with past claims regarding forgetting rates for implicit and explicit memory. Specifically, Schacter (1987) has claimed that when compared with explicit memory (often based on recognition performance), implicit memory as measured by stem completion tasks had a faster rate of forgetting. Past studies have shown this claim to be unsupported for study–test delays up to 90 min (McBride &

Dosher, 1997, 1999). Schacter (1987) also claimed that implicit memory engaged during fragment completion tasks had a slower rate of forgetting than explicit memory. As with the difference claimed for stem completion, the results of the current study are inconsistent with forgetting rate differences for implicit and explicit memory based on fragment completion performance. In particular, Experiment 1 showed similar forgetting rates for implicit and explicit memory, while Experiment 2 showed that forgetting rates are similar for estimates of conscious and automatic memory for retention delays up to 45 min. This result was not model-dependent: Both the non-high-threshold (Jacoby-based) model and the high-threshold (guessing-elaborated) model estimates showed similar rates of decline for *C* and *A*.

Implications for Systems View

These results can be interpreted with regard to the memory systems view as providing support for a single memory system responsible for conscious and automatic memory or as support for separate systems that both have the same rate of forgetting. In other words, implicit and explicit memory might be controlled by one memory system with a single forgetting rate or each might be controlled by a different system and both systems may lose information at the same rate.

Each interpretation is compatible with proposed models of implicit and explicit memory. For example, according to the MATRIX model of memory (Humphreys, Bain, & Pike, 1989), implicit and explicit memory are differentiated by whether or not a context is available for retrieval. Items are represented by a single trace. Context is available for explicit retrieval, but not for implicit retrieval. Since the same trace of the study episode is accessed for both memory processes, a single rate of forgetting might describe both types of memory. This model may be compatible with a range of dependence between implicit and explicit performance. The contribution of the same trace to both implicit and explicit tasks suggests a correlation, but this may be modified by the broad contributions of memory traces from other contexts in implicit task performance. In any event, both full independence (Jacoby) models and dependence (source) models of the process dissociation procedure provided satisfactory accounts of the data.

The REM model (Shiffrin & Steyvers, 1997), on the other hand, proposes that implicit and explicit memory access different traces of an item. Explicit memory relies on an episodic trace, while implicit memory relies on a lexical trace of an item. Forgetting is assumed to reflect changes in the context codes of each trace over a period of time. Context changes occur for both episodic and lexical traces in the same way, which could result in a single rate of decline for both trace types. This model is consistent with separable systems for implicit and explicit memory, each with approximately the same rate of forgetting.

Application of quantitative models of memory, such as the MATRIX or REM model, to the detailed task performance would require further work and specification. However, both single memory system and dual system explanations are reasonable and consistent with proposed models of implicit and explicit memory processes, and with data from these and other experiments.

Summary

The two experiments in the current experiment showed consistent results. For delays up to 45 min, no forgetting rate differences are evident for explicit and implicit memory or for conscious and automatic memory when measured by fragment completion task performance. In addition, the form of forgetting in fragment completion is consistent with forgetting seen in past studies with similar stem completion tasks (McBride & Dosher, 1997, 1999; Sloman et al., 1988). This form displays a rapid decline in performance up to about 15 min, and then a very slow decline in performance to 90 min delays. These results are not consistent with claims that implicit and explicit memory decay at different rates for delays in this range. The results are also not consistent with claims that the forgetting rate differences between implicit and explicit memory depend on the task used to measure these processes.

APPENDIX A

Below is a list of all target stimuli used in Experiments 1 and 2.

Fragment	Target solution
_ _age	adage
ad_i_e	admire
a_ _ent	advent
a_e_t	alert
_n_le	angle
a_ _end	ascend
_ _ide	aside
b_ste_	baster
bl_n_	blind
_oa_t	boast
_ot_ _r	bother
_ rav_	brave
_ri_k	brink
bu_k_ _	bucket
_u_ge	budge
bu_ge_	budget
c_nd_ _	candle
ca_ _on	canyon
_a_tl_	castle
c_v_r_	cavern
ch_r_s	charts
ci_i_	civil
c_ _ss	class
_l_v_r	clever
_l_ _nt	client
c_me_ _	comedy
_o_ch	couch
_ou_t	count
_ov_r	cover
_ra_t	craft
c_ee_	creep
_r_wn	crown
_r_ _se	cruise
de_l_	dealt
de_i_	debit
d_ _ks	decks
d_c_y	decoy
de_ot_	denote
d_si_ _	desire
d_vi_e	divide
_o_gh	dough
e_ti_ _	entity
e_a_e	evade
_xc_ _e	excite
e_u_e	exude
_ab_e	fable
_al_ _n	falcon
_all_w	fallow
_a_ter	falter
_a_gs	fangs
_e_st	feast
_ie_d	field
_il_er	filler
f_a_e	flame
_li_g	fling
fl_ _t	flint
fl_ _r	flour
_low_r	flower
lun	flunk
f_u_e	flute
oca	focal
_ _cus	focus
_ol_er	folder
_on_er	fonder
_ra_d	fraud
fr_e_	fried
_r_it	fruit
_r_st	frost
_a_h_r	gather
_au_e	gauge
g_nt_ _	gently
go_ _ _in	goblin
g_ _gle	goggle
_op_ _r	gopher
g_ _ve	grave
g_ee_	greed
_r_ll	grill
gr_p_	gripe
g_ou_	group
_r_ws	grows

APPENDIX A—*Continued*

Below is a list of all target stimuli used in Experiments 1 and 2.

Fragment	Target solution	Fragment	Target solution
ha_d_ _	harder	ne_ _ _r	nectar
he_ _ _t	height	_o_th	north
hi_ _er	hinder	_liv_	olive
_ _r_r	horror	o_e_	outer
_or_e	horse	par_o_	parlor
_umb_e	humble	_ec_ _d	pecked
in_ _r	infer	_o_nd	pound
in_a_e	inhale	p_ _ _it	pulpit
i_la_d	inland	_ur_l_	purple
in_en_	invent	qu_r_ _	quarts
i_se_ _	itself	qu_t_	quote
je_ _y	jerky	_ant_	rants
_ _ck_y	jockey	re_d_	reads
_oi_t	joint	_ea_o_	reason
_et_l_	kettle	_e_el	rebel
l_ne_	lanes	_in_s	rings
l_st_ _	lastly	_ad_er	sadder
_at_h	latch	s_an_	slant
l_a_y	leaky	sp_ _k	spark
_e_se	lease	s_i_t	spilt
_e_on	lemon	sp_ _e	spite
_ev_r	lever	_p_o_	spoon
l_be_	libel	s_ee_	steel
lo_k_ _	locker	_t_ne	stone
l_ _ty	lofty	st_ _k	stork
l_r_ _	lyric	s_r_ _e	strike
_al_c_	malice	s_u_k	stuck
m_ _or	manor	_ab_ _t	tablet
ma_k_ _	marker	t_mp_ _	tamper
_arr_w	marrow	t_ _l_r	teller
_en_ _r	mentor	_r_mp	tramp
m_ _ne_	moaned	_u_or	tutor
_on_ _y	monkey	t_in_	twins
oos	moose	u_ _er	ulcer
ora	moral	v_ _or	vapor
ous	mouse	v_ol_ _	violet
ule	mules	wa_ _u_	walnut
m_sse_	mussel	_eav_	weave
na_ _l	nasal	w_ _te	white
n_ti_ _	native	_el_ow	yellow

APPENDIX B

Response frequency data for Experiment 2 are given below.

Condition	Targets	Alternates	No answers
Inclusion			
Semantic			
5	185	60	25
10	158	71	41
15	152	79	39
40	99	113	58
80	75	117	78
120	83	136	51
240	68	127	75
Graphemic			
5	132	96	42
10	122	108	40
15	104	116	50
40	81	131	58
80	59	139	72
120	64	146	60
240	62	142	66
Unstudied	70	290	180
Exclusion			
Semantic			
5	30	167	83
10	33	161	87
15	31	169	80
40	27	170	83
80	37	163	79
120	35	171	73
240	30	181	69
Graphemic			
5	82	147	51
10	74	139	67
15	73	152	54
40	50	161	69
80	69	140	71
120	78	133	69
240	69	146	65
Unstudied	61	365	133

APPENDIX C

Predicted frequency values from multinomial model fits for each response category are given below.

Condition/lag	Model: Non-high			High			Source		
	T	A	X	T	A	X	T	A	X
Inclusion–semantic									
5	185	55	30	184	55	31	185	55	30
10	158	72	40	157	72	40	158	72	40
15	152	76	42	151	76	42	152	76	42
40	99	110	61	99	110	61	99	110	61
80	75	122	73	75	122	74	75	122	74
120	83	124	63	83	124	63	83	124	63
240	68	128	74	68	128	74	68	128	74
Exclusion–semantic									
5	30	179	71	30	183	67	30	179	71
10	33	173	75	33	176	72	33	173	75
15	31	179	70	31	182	67	31	180	69
40	27	179	74	27	181	72	27	180	73
80	37	170	72	37	171	71	37	171	71
120	35	173	71	35	174	70	35	174	70
240	30	180	70	30	181	69	30	181	69
Inclusion–graphemic									
5	132	89	49	132	89	49	132	89	49
10	122	95	53	122	95	53	122	95	53
15	104	107	59	104	107	59	104	107	59
40	81	122	67	81	122	67	81	122	67
80	63	129	78	64	128	77	63	129	78
120	70	133	67	71	132	67	70	133	68
240	64	131	75	66	130	74	64	131	75
Exclusion–graphemic									
5	82	142	56	82	143	56	82	142	56
10	74	144	62	74	144	62	74	144	62
15	73	148	58	73	148	58	73	148	58
40	50	163	67	50	163	67	50	163	67
80	65	151	64	64	152	65	65	151	64
120	72	147	61	71	148	61	72	147	61
240	67	154	59	65	155	60	67	154	60
Inclusion–unstudied	70	302	168	70	302	168	64	306	170
Exclusion–unstudied	61	348	150	60	346	153	67	344	148

APPENDIX D

A generate-source model was fit to the frequency data for Experiment 2. Parameter estimates from this model fit can be seen in Table 6. This model estimates a parameter for generating the target (*G*). If a target is generated, a correct source match for the target as studied (*S*) is possible. If the target is not initially generated, an alternate word may instead be generated with probability *W*. This alternate word will undergo a source evaluation, where it may be incorrectly identified as studied (S'). This source model fit the data well. All G^2 values for the source model are lower than the G^2 values for the high-threshold model. See Fig. 9 for a pictorial representation of the source model.

As with the other multinomial model estimates, composite power fits were performed. A four λ, four β, and four γ power function fit the data rather well with $R^2 = .98$. A fit with a single β resulted in a significantly worse fit to the data, $R^2 = .96$, $F(3,16) = 5.99$, $p < .05$; however, a fit with two rate parameters, one for the S_s parameter and one rate for all other processes, fit the data as well as the four β function, $R^2 = .98$, $F(2,16) = 0.61$, $p > .05$. A summary of this fit can be seen in Table 7. This result indicates that there is no evidence of significant rate differences for the generate target and source match processes. Instead, it appears that only the source match process for graphemic study declines at a slower rate. Figure 10 displays the 424 power fit described above along with the data points for each condition. It should also be noted that the *S* estimates for the source model were more variable than the *C* estimates for the other two models fit to the data. This variability is due to the conditional nature of the source model. Both the non-high- and high-threshold models are independence models. Overall, the conclusion for the source model is consistent with conclusions reached for the other models. The only difference is that the S_s process appears to have a slower rate of decline than the other processes. This difference is likely due to the high initial values and low ending values for these estimates.

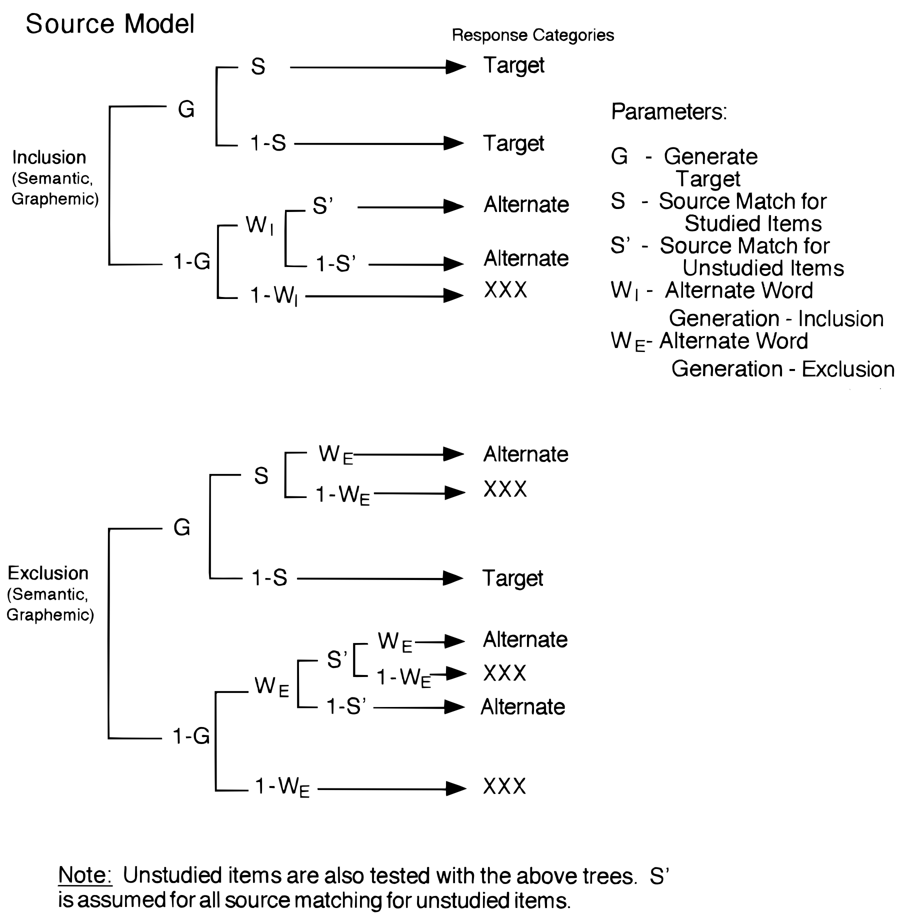

FIG. 9. A multinomial process tree model that assumes dependence between generating target (*G*) and source match (*S*) parameters. An appropriate source match (studied/unstudied) is only possible if the target is initially generated. Separate trees are shown for each task.

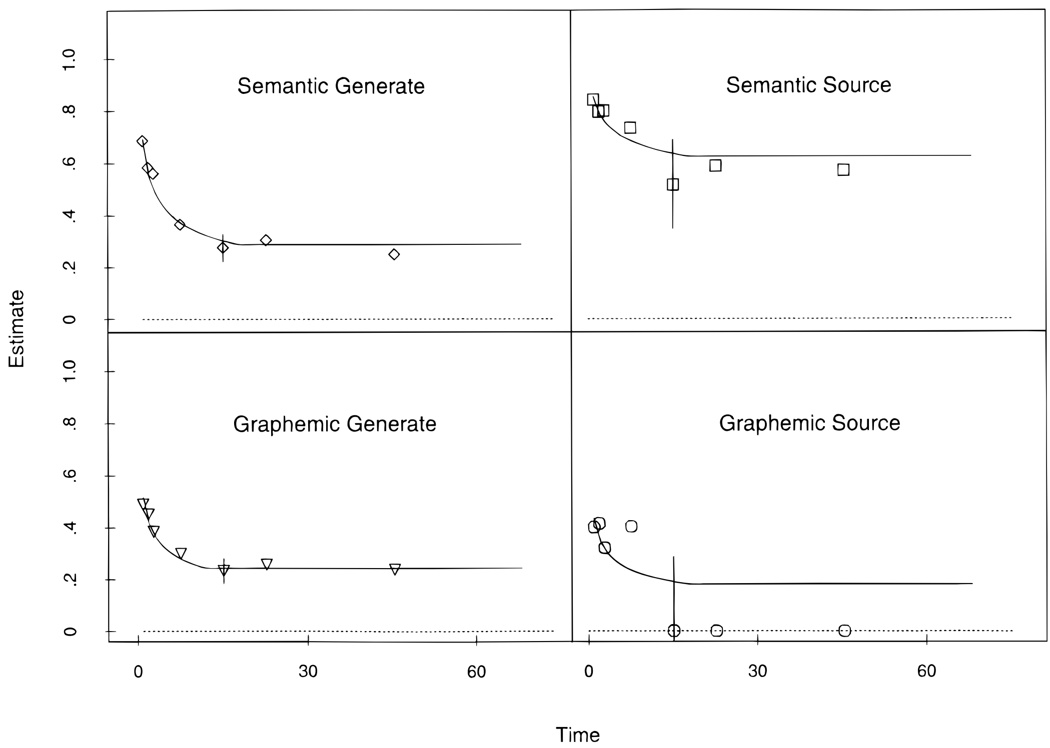

FIG. 10. Model estimates of the source model for *G* and *S* for Experiment 2. Estimates for each study/test condition are shown in a separate panel. Lines overlaid represent fitted values of the single β composite power function. Ninety-five percent confidence intervals (as calculated by the Hu, 1991, program) are shown on representative points (80-item lag, 15.2-min delay) in each panel.

REFERENCES

Batchelder, W. H., & Riefer, D. M. (1990). Multinomial processing models of source monitoring. *Psychological Review*, **97**, 548–564.

Batchelder, W. H., & Riefer, D. M. (1999). Theoretical and empirical review of multinomial process tree modeling. *Psychonomic Bulletin & Review*, **6**, 57–86.

Brown, A. S., & Mitchell, D. B. (1994). A reevaluation of semantic versus nonsemantic processing in implicit memory. *Memory & Cognition*, **22**, 533–541.

Buchner, A., Erdfelder, E., & Vaterrodt-Plünnecke, B. (1995). Toward unbiased measurement of conscious and unconscious memory processes within the process dissociation framework. *Journal of Experimental Psychology: General*, **124**, 137–160.

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.

Craik, F. I. M., Moscovitch, M., & McDowd, J. M. (1994). Contributions of surface and conceptual information to performance on implicit and explicit memory tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**, 864–875.

Curran, T., & Hintzman, D. L. (1995). Violations of the independence assumption in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **21**, 531–547.

Curran, T., & Hintzman, D. L. (1997). Consequences and causes of correlations in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**, 496–504.

Dosher, B. A., & Rosedale, G. (1991). Judgments of semantic and episodic relatedness: Common time-course and failure of segregation. *Journal of Memory and Language*, **30**, 125–160.

Graf, P., & Komatsu, S. (1994). Process dissociation procedure: Handle with caution! *European Journal of Psychology*, **6**, 113–129.

Hamann, S. B., & Squire, L. R. (1996). Level-of-processing effects in word-completion priming: A neuropsychological study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **22**, 933–947.

Hintzman, D. L., & Curran, T. (1997). More than one way to violate independence: Reply to Jacoby and Shrout (1997). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**, 511–513.

Hu, X. (1991). Statistical inference program for multinomial binary tree models [computer program]. Irvine: University of California, Irvine.

Humphreys, M. S., Bain, J. D., & Pike, R. (1989). Different ways to cue a coherent memory system: A theory for episodic, semantic, and procedural tasks. *Psychological Review*, **96**, 208–233.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, **30**, 513–541.

Jacoby, L. L., Begg, I. M., & Toth, J. P. (1997). In defense of functional independence: Violations of assumptions underlying the process-dissociation procedure? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**, 484–495.

Jacoby, L. L., & Shrout, P. E. (1997). Toward a psychometric analysis of violations of the independence assumption in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**, 505–510.

Jacoby, L. L., Toth, J. P., & Yonelinas, A. P. (1993). Separating conscious and unconscious influences of memory: Measuring recollection. *Journal of Experimental Psychology: General*, **122**, 139–154.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. *Canadian Journal of Psychology*, **36**, 300–324.

Komatsu, S., & Ohta, N. (1984). Priming effects in word-fragment completion for short- and long-term retention intervals. *Japanese Psychological Research*, **26**, 194–200.

Loftus, G. R. (1985). Evaluating forgetting curves. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11**, 397–406.

McBride, D. M., & Dosher, B. A. (1997). A comparison of forgetting in an implicit and explicit memory task. *Journal of Experimental Psychology: General*, **126**, 371–392.

McBride, D. M., & Dosher, B. A. (1999). Forgetting rates are comparable in conscious and automatic memory: A process dissociation study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**, 583–607.

Nadel, L. (1994). Multiple memory systems: What and why, an update. In D. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 39–63). Cambridge, MA: MIT Press.

Olofsson, U. (1995). Retention interval, response competition and word familiarity effects in primed fragment completion. *European Journal of Cognitive Psychology*, **7**, 131–143.

Rajaram, S., & Roediger, H. L., III, (1993). Direct comparison of four implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **19**, 765–776.

Richardson-Klavehn, A., & Gardiner, J. M. (1995). Retrieval volition and memorial awareness in stem completion: An empirical analysis. *Psychological Research*, **57**, 166–178.

Riefer, D. M., & Batchelder, W. H. (1988). Multinomial modeling and the measurement of cognitive processes. *Psychological Review*, **95**, 318–339.

Roediger, H. L., III, & Blaxton, T. A. (1987). Effects of varying modality, surface features, and retention interval on priming in word-fragment completion. *Memory & Cognition*, **15**, 379–388.

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

Roediger, H. L., III, Weldon, M. S., Stadler, M. A., & Riegler, G. H. (1992). Direct comparison of two implicit memory tests: Word fragment and word stem completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **18**, 1251–1269.

Russo, R., Cullis, A. M., & Parkin, A. J. (1998). Consequences of violating the assumption of independence in the process dissociation procedure: A word fragment completion study. *Memory & Cognition*, **26**, 617–632.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **13**, 501–518.

Schacter, D. L. (1992). Priming and multiple memory systems: Perceptual mechanisms of implicit memory. *Journal of Cognitive Neuroscience*, **4**, 244–256.

Schacter, D. L., Bowers, J., & Booker, J. (1989). Intention, awareness, and implicit memory: The retrieval intentionality criterion. In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 47–65). Hillsdale, NJ: Erlbaum.

Schacter, D. L., & Tulving, E. (1994). What are the memory systems of 1994? In D. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 1–38). Cambridge, MA: MIT Press.

Shiffrin, R. M., & Steyvers, M. (1997). A model for recognition memory: REM—Retrieving effectively from memory. *Psychonomic Bulletin and Review*, **4**, 145–166.

Sloman, S. A, Hayman, C. G., Ohta, N., Law, J., & Tulving, E. (1988). Forgetting in primed fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **14**, 223–239.

Snodgrass, J. G., & Surprenant, A. (1989). Effect of retention interval on implicit and explicit memory for pictures. *Bulletin of the Psychonomic Society*, **27**, 395–398.

Squire, L. R. (1994). Declarative and nondeclarative memory: Multiple brain systems supporting learning and memory. In D. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 203–231). Cambridge, MA: Harvard Univ. Press.

Squire, L. R. (1995). Biological foundations of accuracy and inaccuracy in memory. In D. Schacter (Ed.), *Memory distortions: How minds, brains, and societies reconstruct the past* (pp. 197–225). Cambridge, MA: Harvard Univ. Press.

Squire, L. R., & Knowlton, B. J. (1994). Memory, hippocampus, and brain systems. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 825–837). Cambridge, MA: MIT Press.

Squire, L. R., Knowlton, B. J., & Musen, G. (1993). The structure and organization of memory. *Annual Review of Psychology*, **44**, 453–495.

Squire, L. R., Shimamura, A. P., & Graf, P. (1987). Strength and duration of priming effects in normal subjects and amnesic patients. *Neuropsychologia*, **25**, 195–210.

Srinivas, K., & Roediger, H. L., III (1990). Classifying implicit memory tests: Category association and anagram solution. *Journal of Memory and Language*, **29**, 389–412.

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

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science*, **247**, 301–306.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **8**, 336–342.

Wannacott, T. H., & Wannacott, R. J. (1981). *Regression: A second course in statistics*. New York: Wiley.

Warrington, E. K., & Weiskrantz, L. (1970). Amnesic syndrome: Consolidation or retrieval? *Nature*, **228**, 628–630.

Warrington, E. K., & Weiskrantz, L. (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia*, **12**, 419–428.

Weldon, M. S. (1993). The time course of perceptual and conceptual contributions to word fragment completion priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **19**, 1010–1023.

Weldon, M. S. (1999). The memory chop shop: Issues in the search for memory systems. In J. K. Foster & M. Jelicic (Eds.), *Memory: Systems, process, or function?* (pp. 162–204). New York: Oxford Univ. Press.

(Received February 11, 2000)
(Revision received January 10, 2001)
(Published online September 17, 2001)