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Role of Elaborative and Perceptual Integrative Processes in Perceptual–Motor Performance

Katherine Verdolini-Marston and David A. Balota

Three experiments address the dependence of both explicit and implicit memory performance on elaborative processes for a perceptual–motor task, pursuit rotor. Explicit memory performance was reflected by recognition of previously encountered pursuit rotor stimuli. Implicit memory performance (priming) was identified in Experiment 1 as an advantage in pursuit rotor performance for old stimuli that Ss failed to explicitly recognize. In Experiments 2 and 3, the types of strategies that Ss engaged in during training and test phases were manipulated. Results indicated that explicit memory performance depended on elaborative processes that emphasized which specific stimuli were encountered, whereas reliable implicit memory performance appeared only under a control no-instruction condition. Discussion focuses on attention to perceptual-integrative processes for priming.

Within the past decade, considerable research has focused on a distinction between explicit and implicit memory performance (see review by Roediger, 1990). Explicit-memory performance is revealed on traditional memory tests such as free recall, cued recall, and recognition tests, in which subjects are required to consciously recollect an earlier episode. Implicit memory performance is reflected by facilitations in performance through previous exposure to a stimulus without specific recollection of earlier episodes (e.g., Graf & Schacter, 1985). Hence, implicit memory performance is reflected by tasks such as word-fragment completion (e.g., Tulving, Schacter, & Stark, 1982; Warrington & Weiskrantz, 1974), perceptual identification (Jacoby & Dallas, 1981), and homophone spelling (e.g., Jacoby & Witherspoon, 1982). In each of these tasks, subjects are not required to consciously recollect an earlier episode to perform the tasks, and yet there are clear benefits from such earlier episodes.

The interest in the implicit–explicit distinction has been nurtured by the possibility that fundamentally different memory systems, processing modes, or both underlie these two types of memory manifestation. Regarding the "systems" viewpoint, data from amnesic subjects have provided evidence for distinct and different neuroanatomical substrates underlying implicit and explicit memory performance (cf. Damasio, 1989; Martone, Butters, Payne, Becker, & Sax, 1984; Zola-Morgan, Squire, & Mishkin, 1982). More germane to our research is the processing distinction. Evidence from both amnesic and healthy, normal subjects suggests that implicit and explicit memory performance appear to depend on different types of encoding processes. In particular, there is evidence indicating that explicit memory performance depends on elaborative processes that relate target events to other contents of memory (e.g., semantic processes), whereas implicit memory performance depends more on integrative processes that reflect the influence of previous exposures on more unitized perceptual representations (e.g., Graf, Mandler, & Haden, 1982; Jacoby & Dallas, 1981). This differential sensitivity to different types of encoding operations laid the groundwork for the dual-process model for implicit and explicit memory performance (see, e.g., Graf et al., 1982; Mandler, 1979, 1980).

Although there has been some compelling support for the processing approach to explicit and implicit memory performance, some exceptions have been reported. These exceptions raise questions about the theoretical utility of distinguishing between these different memory manifestations on the basis of processing characteristics. One of the best examples of such an exception is a study reported by Blaxton (1989, Experiment 1). In Blaxton's study, both explicit and implicit memory performance benefited from elaborative processing, in some cases, and from perceptual processing, in other cases, depending on the retrieval demands of the memory test. That is, performance on two explicit memory tests (free recall and semantically cued recall) and on one implicit memory test (a test of general knowledge) was best following the *elaborative* processing of target stimuli, and performance on one explicit memory test (graphemically cued recall) and on one implicit memory test (word-fragment completion) was best following the simple *perceptual* processing of the targets. The importance of these results is that it would appear that explicit and implicit memory performance may not be fully distinguished by distinct processing modalities but rather might be better understood in terms of the match between encoding operations and the retrieval demands of the memory test. The emphasis on the match between encoding and retrieval operations has been most clearly detailed in the *transfer-appropriate processing* frame-

Katherine Verdolini-Marston and David A. Balota, Department of Psychology, Washington University.

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Correspondence concerning this article should be addressed to Katherine Verdolini-Marston, who is now at the Department of Speech Pathology and Audiology, University of Iowa, Iowa City, Iowa 52242. Electronic mail may be sent to verdolini@wjshc-po.shc.uiowa.edu.

work (for further discussion, see Roediger, Srinivas, & Weldon, 1989; Roediger, Weldon, & Challis, 1989; also see Morris, Bransford, & Franks, 1977).[1]

One of the goals of our research was to provide further evidence regarding the notion that explicit and implicit memory performance are regulated by qualitatively different types of encoding processes (e.g., elaborative and integrative processes, respectively). In pursuit of this goal, we attempted to assess the sensitivity of both implicit and explicit memory performance to two different types of elaborative processes. According to the dual-process (dissociation) model, implicit memory should be relatively unaffected by distinct types of elaborative processes because this type of memory performance is relatively insensitive to elaborative encoding operations in general. However, different types of elaborative processes should modulate explicit memory performance. On the other hand, according to the transfer-appropriate processing framework, one may find an influence of type of elaborative processing on both explicit and implicit memory performance because the strongest predictor of performance within this approach is the degree to which the encoding operations match the retrieval operations that are demanded by the memory tests. Hence, the crucial dimension is not the type of processing but rather the match between the encoding and retrieval operations.

A critical aspect of our research is the identification of the appropriate two classes of elaborative encoding operations. The two types of elaborative processes selected were based on the views expressed by a number of memory researchers regarding explicit and implicit memory performance. It has been pointed out that explicit memory performance involves the unique specification of events (see, e.g., Damasio, 1989; Tulving, 1972), and according to some speculations, implicit memory performance involves procedures and operations, or "knowing how" to perform a task (Cohen & Squire, 1980; Squire, 1986; Squire & Cohen, 1984). Thus, in our research, one class of elaborative encoding conditions emphasized which specific stimuli subjects encountered, and the other class emphasized how to do the experimental task. According to a transfer-appropriate processing view, one might expect that elaborative processes that individuate stimuli would benefit explicit memory performance, whereas elaborative processes that emphasize how to do a task would benefit implicit memory performance. In contrast, on the basis of an unembellished dual-process model, one might expect that the different types of elaborative processes would be relatively ineffective in modulating implicit memory performance and would be primarily effective in modulating explicit memory performance.

In our study, a perceptual-motor task (pursuit rotor) was used to address the influence of these two types of elaborative processes on explicit and implicit memory performance. The selection of a perceptual-motor task is important for the following three reasons: First, there is anecdotal evidence that suggests that elaborative processes can enhance implicit type memory manifestations in the perceptual-motor domain. Specifically, some professional perceptual-motor trainers claim that metaphoric images, which relate target productions to other contents of memory, promote benefits in perceptual-motor performance without reference to previous training episodes. For example, Fleshman (1984) emphasized the use of the metaphors of "the sea within" and "the sea without" to facilitate acquisition of graceful dance movements. Lessac (1967) described speech and voice as an "orchestra" to facilitate acquisition of resonant voice and intelligible speech for theater. If in fact such metaphors facilitate implicit perceptual-motor memory performance following training, it might be possible to show a dependence of implicit memory performance on elaborative processes by incorporating (elaborative) metaphors during training.

The second reason for using a perceptual-motor task was related to the anticipated dependence of implicit memory performance on elaborative processes that emphasize how to do a task. Although implicit verbal memory, in general, supposedly depends on procedures and operations or on knowing how (Cohen & Squire, 1980; Squire, 1986; Squire & Cohen, 1984), the relevance of knowing how would appear, at least at a surface level, to be stronger for a perceptual-motor task, as compared with verbal tasks that require subjects to complete word fragments or to identify rapidly presented words.

The third and final reason we used a perceptual-motor task was that only a limited number of studies have assessed the mental processes that mediate explicit and implicit memory performance beyond the verbal domain (e.g., Nissen & Bullemer, 1987; Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). Although the influence of elaborative processing on implicit memory performance is relatively rare in the verbal domain, such a relationship may be more readily obtained in other domains. As pointed out previously, the perceptual-motor domain is a prime candidate for such a demonstration.

In summary, our purpose was to provide further evidence regarding the dissociation between explicit and implicit memory performance as a function of processing level in a perceptual-motor task. We assessed the influence of two types of elaborative processes on implicit and explicit memory performance. On the basis of theoretical descriptions regarding the operations that underlie implicit and explicit memory performance, one might expect that elaborative processes that emphasize which unique stimuli were encountered would benefit explicit memory performance, whereas elaborative processes that emphasize knowing how to do a task would benefit implicit memory performance, especially on a perceptual-motor task. On the other hand, according to an unembellished dual-process (dissociation) model, one might expect that explicit memory performance would be especially sensitive to the type of elaborative processing, whereas implicit memory performance would be relatively uninfluenced.

Overview of the Experiments

The subjects' task in each experiment was to track a rotating visual target with a wand (pursuit rotor task). In each experi-

[1] Note that at a general level, the dual-process model can also be considered under the rubric of a transfer-appropriate processing approach (Graf & Ryan, 1990). However, in this article, transfer-appropriate processing refers to the specific version described by Roediger and colleagues.

ment, subjects tracked several different targets that were created by varying target radii and target speeds. Each specific speed–radius combination is referred to as a *stimulus*. The measure of general perceptual–motor skill was time on target (TOT), in seconds, for each minute of practice.

During an initial phase, subjects first warmed up on the pursuit rotor task by practicing on relatively easy stimuli (stimuli with comparatively low tangential velocities). Subjects then received several more difficult, critical stimuli during the training phase. After a delay, subjects returned for a test phase. During the test phase, subjects first practiced on the same warm-up stimuli as they had done previously and then received a set of critical stimuli. Some of these critical stimuli were old, and some were new. After each critical test trial, subjects responded (yes or no) as to whether they recognized the preceding stimulus from the training phase. This was the first indication that there would be an explicit memory test. Proportion of correct responses on the recognition test constituted the measure of explicit-memory performance. Chance results on this test were reflected by a recognition score of .50.

The purpose of Experiment 1 was to provide evidence of implicit perceptual–motor memory performance, defined as a facilitation in perceptual–motor performance (in TOT) following practice, without explicit reference to previous learning episodes. To be consistent with most previous studies in the verbal domain, an additional requirement for the measure of implicit memory performance was that facilitations be shown for specific stimuli that subjects did not reliably recognize as old (priming without awareness).

The purpose of Experiments 2 and 3 was to address the primary theoretical question of interest, that is, the role of distinct types of elaborative processes for explicit and implicit perceptual–motor memory performance. In these experiments, the strategies that subjects engaged in were manipulated, and the effects on explicit and implicit memory performance were observed. Specifically, subjects in different groups received (a) elaborative processing instructions that emphasized which specific stimuli were encountered, (b) elaborative processing instructions that emphasized how to do the pursuit rotor task, (c) perceptual–integrative instructions that emphasized attention to the surface characteristics of the stimuli (Experiments 2 and 3), or (d) no instructions about mental strategies (Experiment 3).

A final introductory comment is worth noting here. The measures of explicit and implicit memory performance involve different scales. That is, the measure of explicit-memory performance was the proportion of correct identifications on a recognition test, whereas the measure of implicit memory performance was facilitation in pursuit rotor performance (in TOT) for previously encountered stimuli. One might ask whether the results for explicit and implicit memory performance could be compared because of these scaling differences. Although it is clearly desirable to use similar scales across measures within an investigation, there was no obvious way to create similar scales for explicit and implicit memory performance in the present experiments. More important, it should also be noted that scaling issues in general pose major interpretative problems when one of the measures under examination is insensitive to experimental manipulations and when the goal is to quantitatively compare changes in different measures as a function of the experimental manipulations. Neither of these problems occurred in this study. To anticipate the results we modulated by processing condition both explicit and implicit memory performance across all the experiments. Thus, neither explicit nor implicit measures of memory performance were insensitive. Furthermore, our purpose was not to quantitatively compare variations in explicit and implicit memory performance as a function of processing condition but rather to detect the dependence of these performance types on various encoding operations. Thus, although scaling differences across implicit and explicit-memory tests are a potential concern in this area of research, these concerns did not compromise our conclusions.

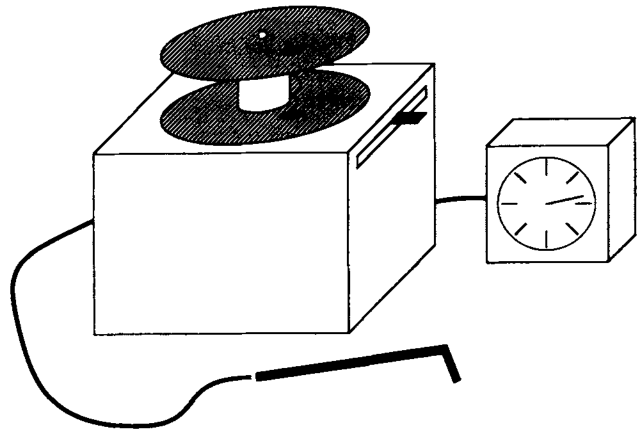

Figure 1. Pursuit rotor equipment used in Experiment 1. It includes modified pursuit rotor, rotary timer, and wand. Replacement disks are not shown.

Experiment 1

As noted, the goal of the first experiment was to identify a measure of implicit perceptual–motor memory performance, which is defined as a performance facilitation (priming) for previously encountered stimuli that subjects do not reliably recognize.

Method

Subjects. Twenty-two healthy adults, 12 men and 10 women ranging from age 18 to 42 years (M = 24.2 years) participated in the experiment as volunteers. With the exception of one subject, all were undergraduate or graduate students at Washington University. All but two subjects were right-handed, according to self-reports.

Apparatus. The modified pursuit rotor used in Experiment 1 is shown in Figure 1. This device consisted of a 20.7 cm × 10.1 cm × 30.1 cm wooden frame that housed one of five disks that rotated in a clockwise direction at 30, 60, or 90 rpm. A copper target with a diameter of 0.95 cm was embedded in each of the disks. For each disk, the center of the target was located at a different distance from the center of the disk: 3.45 cm, 5.39 cm, 7.27 cm, 9.15 cm, and 11.04 cm, and 12.94 cm (Disks 1, 2, 3, 4, 5, and 6, respectively). When the metal stylus (Lafayette Instrument Company Pursuit Rotor Stylus) made contact with the copper target, a timer (Lafayette Instrument Company rotary timer) was driven and indicated TOT in 10-ms increments.

Table 1
Performance in Training and Test Phases in Experiment 1 (N = 22)

Measure	Training: TOT	Test: TOT, old stimuli	Test: TOT, new stimuli	Implicit memory: TOT, old–new stimuli	Explicit memory: PCR
M	22.81 s	32.50 s	30.37 s	2.13 s*	.54
SD	5.82 s	6.53 s	7.74 s	3.45 s	.19

Note. TOT = time-on-target; TOT advantage of old over new test stimuli in implicit-memory performance; PCR = proportion correct on recognition test.
*$p < .01$.

A cassette recorder was used to deliver instructions about when to start and stop pursuit-rotor practice for all phases of the experiment.

Stimulus materials. Warm-up stimuli involved Disk 1 that was presented at 30, 60, and 90 rpm. Critical training stimuli were drawn from a pool of 8 stimuli, a subset of 15 possible stimuli, involving Disks 2, 3, 4, 5, and 6, presented at 30, 60, and 90 rpm. Each stimulus involved a unique combination of target radius and target speed. For each subject, 4 different, critical training stimuli were selected from the pool of 8 stimuli, and each of the 4 stimuli was presented three times during training. Each training set of 4 critical stimuli exhibited the following characteristics: (a) The average tangential velocity across the 4 different stimuli was approximately 60 cm/s and (b) for each critical training stimulus that was presented to a given subject, another subject received a different critical stimulus with approximately the same tangential velocity. Critical test stimuli included all 8 stimuli from the selected stimulus pool, 4 old stimuli and 4 new stimuli. For each subject, test stimuli were ordered according to the following constraints: (a) The average tangential velocity of stimuli in the first and second halves of the test sequence was similar, ranging from approximately 59 cm/s to 62 cm/s, and (b) 2 old and 2 new stimuli appeared in each half of the test sequence. All stimuli were counterbalanced across subjects so that each stimulus appeared equally often as an old and as a new stimulus.

Procedure and design. For all pursuit rotor trials, subjects held the tracking wand in the dominant hand. Throughout the experiment, subjects received 1-min pursuit rotor trials that were separated by 1-min rest periods. Subjects first received the warm-up stimuli. Including 3 min of practice and 2 min of rest, the first warm-up phase lasted 5 min. Following the warm-up phase, subjects received the critical training stimuli. Including 12 min of practice (4 stimuli by 3 trials each) and 11 min of rest, the critical training phase lasted 23 min.

Approximately 24 hr later (22.4 to 27.8 hr), subjects returned for the test phase. For this phase, subjects first warmed up on the same warm-up stimuli they had received the previous day. Following the warm-up phase, subjects received the critical test stimuli and also the recognition test. Including 8 min of pursuit rotor performance and 7 min of rest, the total time for the critical test phase was 15 min.

Throughout the experiment, TOT information was provided immediately after each trial, except during the critical test phase. During the test phase, subjects first provided recognition responses and then were informed about TOT. Additional information about performance was provided by audible clicks in the pursuit rotor apparatus each time the tracking wand went on or off target.

For both explicit memory (recognition) performance and implicit memory (priming) performance, we used a one-way (old vs. new stimulus) within-subject design.

Results and Discussion

As displayed in Table 1, subjects' performance (in TOT) on the pursuit rotor task improved from training to test phases. The average TOT for critical training stimuli was 22.81 s, whereas the average TOT for the same stimuli at test was 32.50 s, and the average TOT for new stimuli of the same approximate difficulty was 30.37 s. Thus, the average TOT for old stimuli was higher than the average TOT for new stimuli during the test phase by a margin of 2.13 s. A one-way, within-subject analysis of variance (ANOVA) confirmed that this performance advantage, or priming, was reliable, $F(1, 21) = 8.36, p < .01, MS_e = 5.95$. Thus, there was clear evidence of performance facilitation for previously encountered stimuli.

The mean proportion of correct identifications on the recognition test was .54. This value, also shown in Table 1, was not reliably different from chance, $z = .37$.

The poor explicit recognition performance might appear a bit surprising, given that each subject received only four different critical stimuli during the training phase and was later required to distinguish this limited number of stimuli among a pool of only eight stimuli. Poor recognition performance was clearly related to the difficulty of remembering not only which target radius was encountered but also the specific radius–speed combination. Thus, even if a subject correctly recognized a disk from the training phase, this would not necessarily lead to correct recognition unless the subject was able to remember the association between target radius and target speed.

In summary, item-specific priming occurred for stimuli that subjects did not reliably recognize. Therefore, the results of Experiment 1 provide evidence of implicit memory performance in a perceptual–motor task.

Experiment 2

The purpose of Experiment 2 was to address the influence of elaborative processes on both explicit and implicit perceptual–motor performance. During both training and test phases, the mental strategies that subjects engaged in were manipulated, and the effect on explicit and implicit memory performance was observed. Two of the mental strategies promoted elaborative processing because they required subjects to relate pursuit rotor stimuli to other contents of memory. One of the elaborative strategies individuated the specific stimuli that subjects received (album condition), and the other elaborative strategy emphasized how to perform the pursuit rotor task in general (stir condition). A third processing condition was intended to promote perceptual processing by directing subjects' attention to the surface characteristics of the stimuli (concentrate condition).

The predictions are relatively straightforward. According to the dual-process model, one should expect that both types of elaborative processing would facilitate explicit memory performance, as compared with the perceptual–concentrate condition. Moreover, depending on the depth of elaborative processing across these two tasks, there may be reliable differences between the two types of elaborative processing in explicit memory performance. Turning to implicit memory performance, according to the dual-processing framework, one should expect performance to be either equivalent across all three conditions or possibly highest in the perceptual–concentrate condition. On the other hand, according to the transfer-appropriate processing framework, one should expect that elaborative processing that individuated the different stimuli should result in superior explicit memory performance and that an elaborative strategy that emphasized how to do the pursuit rotor task should result in superior implicit memory performance.

Method

Subjects. Ninety-six healthy adults, 72 women and 24 men, volunteered for the experiment. Subjects were recruited from undergraduate and graduate classes at Washington University, as well as from the local community. Ages ranged from 17 to 46 years ($M = 31.2$ years). Twenty-four women and 8 men were assigned to each of the three experimental groups. On the basis of subject reports, 87 subjects were right-handed, 7 were left-handed, and 2 were ambidextrous.

Apparatus. The pursuit rotor equipment was updated with a more recent apparatus, a Lafayette Instrument Company Photoelectric Rotary Pursuit (Model 30014), connected to a Lafayette digital clock/counter (Model 54035). The pursuit rotor machine was 36 cm wide × 36 cm deep × 21 cm high. Five removable glass plates that were placed on the top of the pursuit rotor machine formed the superior surface. These plates were painted black, except for a transparent circular path 2.0 cm wide. For each of the five plates, the radius of the circular path was different: 3.4 cm, 5.0 cm, 6.6 cm, 8.2 cm, and 9.8 cm for Plates 1, 2, 3, 4, and 5, respectively.

When the machine was activated, a light spun in a clockwise direction beneath the surface of whichever plate was installed and appeared as a target of 2.0 cm × 1.7 cm within the circular path of the plate. The speed of light rotation could be varied continuously from 1 to 100 rpm. A photoelectric sensor embedded in a hand-held wand activated a digital counter when the wand was directly above the light. The counter measured TOT to the nearest millisecond. The sensitivity of the light receptor was set at the maximum level throughout the experiment.

Stimulus materials. Both training and test phases began with three warm-up stimuli, which involved Plate 1, and target rotations of 30 rpm, 60 rpm, and 100 rpm.

For each subject, critical stimuli for training and test phases included four different stimuli from a pool of eight stimuli involving four plates (Plates 2, 3, 4, and 5) and two rotational speeds (60 rpm and 100 rpm). As in Experiment 1, each different critical stimulus involved a unique combination of target radius and target speed. For a given subject, each of the four different critical training stimuli was repeated three times, and together, the set of four stimuli reflected the following constraints: (a) The average target tangential velocities across the stimuli ranged from approximately 60 cm/s to 64 cm/s; (b) the four different stimuli included one exemplar each of Plates 2, 3, 4, and 5; (c) a given plate was always presented with the same rpm (60 rpm or 100 rpm); (d) two of the four stimuli had rotations of 60 rpm, and two had rotations of 100 rpm; and (e) the same stimulus was not repeated on successive trials, and each of the four different stimuli appeared at least once within the first five trials.

Critical stimuli for the test phase included all exemplars from the pool of eight stimuli. Two old stimuli and two new stimuli appeared in each half of each test sequence, and average tangential velocities for stimuli in the first and second halves of each test sequence were similar, ranging from 60 cm/s to 64 cm/s. As in Experiment 1, each stimulus was counterbalanced so that it occurred on an equal number of trials in the old and new conditions across subjects.

Procedure and design. The principal difference in the procedure, as compared with Experiment 1, was the introduction of mental strategies during training and test phases. Following warm-up trials, which lasted 5 min including 3 practice min and 2 rest min, subjects were given one of three different instructions: album, stir, or concentrate. (The full instructions are described elsewhere, see Verdolini-Marston, 1991.) Briefly, in the concentrate group, subjects were instructed to use the pursuit rotor task as an exercise in concentration and to attend to the rotating target and to the target's path. These instructions were assumed to promote perceptual processing, that is, attention to the surface characteristics of the stimuli. In the stir group, subjects were instructed to think of the pursuit rotor task as stirring in a bowl (the target path) with a wooden spoon (the tracking wand). The assumption was that these instructions promoted elaborative processing because they emphasized the relation between the pursuit rotor stimuli and other contents of memory. It was further assumed that these instructions emphasized how to do the pursuit rotor task, on the basis of the results of a two-stage pilot study.[2]

Finally, in the album group, subjects were instructed to view the pursuit rotor machine as a record player and the four different target paths as different songs on an album. Subjects were asked to mentally hear a specific song during critical trials, depending on which target path was presented, and to hear each song at a speed that depended on the speed of target rotation. The assumption was that these instructions also promoted elaborative processing because they encouraged the relating of pursuit rotor stimuli to other contents of memory. It was further assumed that these instructions emphasized which specific stimuli subjects received for practice because each pursuit rotor stimulus corresponded to a unique combination of mental song and mental song speed.

After receiving instructions about mental strategies, subjects were given the opportunity to practice their respective mental strategies briefly before proceeding with the training trials. After each critical trial, subjects indicated (yes or no) whether they had used the intended mental strategy during the preceding trial, and they rated both the clarity and persistence of the strategy during the preceding trial on a 5-point scale. This enforced the processing strategies by introducing some form of accountability.

In this experiment, 1-min critical trials during the training phase (and also during the test phase) were separated by rest intervals of 1 min 15 s, as opposed to rest intervals of 1 min as in Experiment 1. In Experiment 2, subjects were reminded of the mental strategies before each trial, and extra time was provided for the reminders. Thus, including 12 min of practice and 13 min 45 s of rest, the critical training phase lasted 25 min 45 s.

Following a rest of 12 min 30 s, subjects returned for the test phase. The delay interval was 12 min 30 s in this experiment, as opposed to 24 hr in Experiment 1. The interval was shortened Experiment 2 because effects of mental strategies on both explicit and implicit memory performance were the focus of interest in Experiment 2, and it is quite possible that explicit memory performance might become insensitive to the manipulations of interest over a 24-hr period. The test phase began with the same warm-up stimuli that preceded the training phase; for these warm-up trials, subjects were told they could use whatever mental strategy they wished. Following the second warm-up,

[2] In the first stage of the pilot study, 8 of 10 subjects generated stirring as an image that they thought would help them to perform the pursuit rotor task. In a second stage, 10 of 20 new subjects preferred the stirring image over a circle-drawing image in terms of perceived usefulness of the images for how to do the pursuit rotor task. Only 5 of these subjects preferred the circle image. Further details about the pilot study are available from Katherine Verdolini-Marston and David A. Balota on request.

Table 2
Performance in Training and Test Phases in Experiment 2 (N = 96)

Group/ measure	Training: TOT	Test: TOT, old stimuli	Test: TOT, new stimuli	Implicit memory TOT, old–new stimuli	Explicit memory: PCR
Concentrate					
M	27.17 s	32.55 s	32.10 s	0.45 s	.51 s
SD	6.08 s	6.01	6.15 s	2.83 s	.15 s
Stir					
M	28.37	32.92 s	32.70 s	0.22	.55 s
SD	6.90 s	7.75 s	7.91 s	2.75 s	.18 s
Album					
M	26.50 s	32.33 s	31.85 s	0.48 s	.65 s*
SD	7.67 s	7.70 s	8.25 s	2.10 s	.19 s
Grand means	27.35 s	32.60 s	32.22 s	0.38 s	.57 s**

Note. TOT = time-on-target; TOT advantage of old over new test stimuli in implicit-memory performance; PCR = proportion correct on recognition test.
*$p < .05$, one-tailed. **$p < .01$ for main effect of group.

which lasted a total of 5 min, subjects received the critical test. Including 8 min of pursuit rotor performance and 8 min 45 s of rest, the final critical phase lasted 16 min 45 s.

For explicit memory (recognition) performance, the design was a one-way (3 mental strategy groups), between-subjects design. For implicit memory (priming) performance, the design was a two-way (2 [old–new status] × 3 [group]), mixed-factor design, with old–new status as a within-subject variable and group as a between-subjects variable.

Results and Discussion

Implicit memory. Table 2 shows that although all groups improved in pursuit rotor performance from training to test phases ($M = 27.35$ s for critical stimuli during the training phase, $M = 32.60$ s for old stimuli during the test phase, and $M = 32.22$ s for new stimuli during the test phase), there was little evidence of an item-specific performance benefit for old over new stimuli in the test phase, for any of the groups. Across groups, the average performance advantage for old stimuli was 0.38 s, and within-group averages ranged from 0.22 s (stir group) to 0.48 s (album group). A 2 (old–new status) × 3 (mental strategy group) mixed-factor ANOVA failed to reveal a significant main effect of priming (old vs. new status), $F(1, 93) = 2.03, p < .16, MS_e = 3.32$. In addition, the interaction of Group × Old–New status, which indicated whether priming differed as a function of group, did not approach significance, $F(2, 93) = 0.10$. Thus, on average, there was little or no evidence of perceptual–motor priming in any of the mental strategy groups.

It is interesting to note that not only were item-specific priming effects similar (null) across strategy groups, but a measure of generalized learning for the pursuit rotor task also did not change across strategy groups. Specifically, if one considers improvements from training items compared with new items in the test phase, there was little evidence of any group differences, $F(2, 93) = 0.89, p < .42, MS_e = 4.81$. Although the main effect of instructional group on general aspects of pursuit rotor skill acquisition is secondary to the main focus of our investigation (i.e., item-specific implicit-memory performance), this pattern is noteworthy because it does not support anecdotal claims of general benefits for a perceptual–motor task with metaphoric (elaborative) processing conditions, even though subjects in our pilot study generally perceived such instructions as facilitatory (stir condition, see Footnote 2).

Explicit memory. As shown in Table 2, explicit recognition performance was clearly influenced by mental strategy. Recognition performance was poorest for the concentrate group (.51), slightly better for the stir group (.55), and considerably better for the album group (.65). A one-way between-subjects ANOVA yielded a main effect of mental strategy, $F(2, 93) = 5.59, p < .006, MS_e = 0.029$. Post hoc Tukey comparisons indicated that explicit recognition performance for the album group was reliably higher than performance for the concentrate group, but none of the other comparisons produced reliable differences. In fact, only recognition performance for the album group was reliably different from chance, $z = 1.75$, $p < .05$, one-tailed.[3,4]

To summarize, elaborative processing instructions resulted in relatively good explicit memory performance but only when these instructions emphasized which unique stimuli subjects received (album instructions). Conversely, none of the instructions, including elaborative processing instructions (stir and album instructions) and perceptual processing instructions (concentrate instructions) resulted in implicit memory performance (priming) that was better than chance.

The failure to obtain any priming in Experiment 2 was puzzling, especially in light of the fact that priming was clearly demonstrated in the first experiment, in which mental strategies were not imposed. Assuming that the results from Experiment 1 were not spurious, one possible explanation is that the strategies developed in Experiment 2 were simply inefficient for implicit memory performance. Thus, if one were to develop

[3] Hits and false alarms were evaluated to determine whether group differences in recognition performance were related to differences in sensitivity, response bias, or both. All groups showed a positive response bias of the same approximate magnitude: For all groups, approximately 65% of recognition responses were yes (66.4% for the concentrate group, 64.5% for the stir group, and 65.6% for the album group). Therefore, changes in recognition as a function of group were not associated with changes in response bias. Rather, recognition differences were attributable to differential sensitivity.

[4] In Experiment 2 and also in Experiment 3, post hoc questioning revealed that subjects were insightful about the relative usefulness of their respective instructions for explicit memory performance. Subjects in the album group rated the instructions as most helpful, whereas most other subjects rated the instructions as not helpful (stir and concentrate groups, Experiment 2) or as helping very little (locomotive and concentrate groups, Experiment 3); recognition data corroborated these impressions. However, subjects were not insightful about the relative usefulness of their instructions for pursuit rotor performance. Subjects in the concentrate and stir groups in particular tended to rate their instructions as quite helpful, whereas subjects in the album group tended to think that their instructions did not help pursuit rotor performance much, or helped less. However, these impressions were unrelated to pursuit rotor performance data. This finding is discussed in detail elsewhere (Verdolini-Marston, 1991).

better elaborative strategies, one might find implicit priming in the pursuit rotor task under such instructions. This possibility was addressed in Experiment 3. In addition, Experiment 3 addressed another simpler hypothesis that we had not considered at the outset. Specifically, it is possible that implicit perceptual–motor memory manifestations, reflected by item-specific priming effects, fail to develop under conditions in which subjects are required to attend to mental strategies.

Experiment 3

The purpose of Experiment 3 was to address the failure to obtain reliable priming in any of the mental strategy groups in Experiment 2. Experiment 3 addressed the hypothesis that some mental strategies (e.g., elaborative strategies that emphasize how to do a task, or even perceptual strategies that emphasize attention to surface characteristics of a stimulus) can result in reliable and even superior priming, but the particular strategies used in Experiment 2 were simply poor ones. Thus, in Experiment 3, an attempt was made to improve the effectiveness of the elaborative strategy that emphasized how to do the pursuit rotor task (stir strategy) and of the perceptual strategy that emphasized attention to surface characteristics of the stimuli (concentrate strategy). In addition, an attempt was made to increase the sensitivity of the priming measure in general by increasing the number of repetitions for each critical training stimulus from three to four. Finally, Experiment 3 also addressed the possibility that perceptual–motor priming fails to develop when mental strategies are imposed. This hypothesis was tested by reintroducing a no-instruction group in Experiment 3. If the results of Experiment 2 were due to the possibility that perceptual–motor priming does not develop with imposed mental strategies, then the results of the third experiment should yield no implicit priming for any of the mental strategy groups and reliable priming for the no-instruction group, as found in Experiment 1.

Method

Subjects. Subjects were 128 healthy adults who volunteered for the experiment. Subjects were again recruited from Washington University and the local community. Ages ranged from 17–44 years (M = 27.5 years). Sixty-three women and 65 men participated, and approximately the same number of women and men were assigned to each of four experimental groups. According to self-reports, 110 subjects were right-handed, 14 were left-handed, and 4 were ambidextrous.

Apparatus and stimulus materials. The same apparatus and stimulus materials used in Experiment 2 were used in Experiment 3.

Procedure and design. The fundamental procedure and design were the same as for Experiment 2, with the exception of the following changes (see Verdolini-Marston, 1991, for further details).

Subjects in the concentrate group received instructions that were similar to those in Experiment 2, with two exceptions that were expected to increase attention to perceptual aspects of the task by reducing competing operations. First, in addition to concentrating on the pursuit rotor circle–light ensemble, subjects were specifically instructed to exclude extraneous thoughts and emotions. Second, subjects were also instructed to use "free and easy breathing" as an aid to limiting performance apprehensions that might distract attention from the perceptual–motor task.

Table 3
Performance in Training and Test Phases in Experiment 3 (N = 128)

Group/ measure	Training: TOT	Test: TOT, old stimuli	Test: TOT, new stimuli	Implicit memory: TOT, old–new stimuli	Explicit memory: PCR
		Mental-strategy groups			
Concentrate					
M	29.02 s	33.97 s	33.57 s	0.40 s	.60 s
SD	6.38 s	7.35 s	7.72 s	2.69 s	.15 s
Locomotive					
M	28.82 s	33.95 s	33.97 s	−0.02 s	.59 s
SD	6.80 s	7.74 s	7.62 s	1.86 s	.13 s
Album					
M	27.19 s	32.62 s	32.66 s	−0.04 s	.79 s**
SD	6.48 s	8.21 s	8.31 s	2.92 s	.20 s
		No-instruction group			
M	28.31 s	35.43 s	34.18 s	1.25 s	.54 s
SD	5.62 s	6.52 s	6.35 s	2.10 s	.17 s
Grand means					
M	28.34 s	33.99 s**	33.60 s	0.39 s*	0.63 s**

Note. TOT = time-on-target; TOT advantage of old over new test stimuli in the implicit-memory performance; PCR = proportion correct on recognition test.
*p < .05 For preplanned comparison between mental-strategy groups and no-instruction group. **p < .01. ***p < .01 For preplanned comparison between mental-strategy groups and no-instruction group.

The stir instructions used in Experiment 2 were substituted with "locomotive" instructions. This change in elaborative processing instructions that emphasized how to do the pursuit rotor task was based on a pilot study.[5] The locomotive instructions required subjects to view the circular target path as a wheel on a locomotive and to view the tracking wand as a rod attached to the target light on the wheel as it turned. The suggestion was that as the wheel turned, it would pull the rod and thus the arm around with it.

Rest periods between critical trials were 1 min in Experiment 3, as in Experiment 1. Rest periods were increased to 1 min 15 s in Experiment 2 to allow for reminders about mental strategies before each practice minute. Reminders were also used in Experiment 3, but the rest intervals were decreased in duration to offset the increase in the overall time required for the experiment as a result of the additional training trial for each stimulus during the training phase.

Including 16 min of training trials (4 stimuli × 4 repetitions) and 15 min of rest, the initial critical phase lasted 31 min. The critical test phase lasted 15 min, including 8 min of practice and 7 min of rest. All other aspects of the procedure and design were similar to Experiment 2.

Results and Discussion

Implicit memory. As shown in Table 3, subjects in all groups improved in pursuit rotor performance from training to test phases (M = 28.34 s for critical stimuli during the training phase, M = 33.99 s for old stimuli during the test phase, and

[5] Specifically, in this pilot study, 12 of 20 subjects preferred the locomotive instructions to stir instructions in terms of perceived usefulness for how to do the pursuit rotor task, as compared with 6 subjects who preferred the stir instructions. Further details are available from K. Verdolini-Marston and David A. Balota.

$M = 33.60$ s for new stimuli during the test phase). More important, however, subjects in the mental strategy groups showed little evidence of a performance advantage for old stimuli over new stimuli during the test phase (i.e., item-specific priming). For these groups, average TOT advantages for old stimuli during the test phase ranged from -0.04 s (album group) to 0.40 s (concentrate group). Individual t tests confirmed that priming was unreliable for all of the mental strategy groups. However, as in Experiment 1, subjects who did not receive any instructions about mental strategies did produce reliable priming; the TOT advantage for old stimuli over new stimuli during the test phase was 1.25 s for the no-instruction group, $t(31) = 3.37$, $p < .01$. Furthermore, although a 2×4 (Old–New Status × Group) mixed-factor ANOVA indicated that the main effects of old–new status (priming), $F(1, 124) = 3.40$, $p < .07$, $MS_e = 2.95$, and the interaction of old–new status by group, $F(3, 124) = 1.97$, $p < .13$, $MS_e = 2.95$, failed to reach significance, a preplanned comparison comparing priming for the no-instruction group with the mean of the priming effects across the mental strategy groups did yield a reliable difference, $t(124) = 2.29$, $p < .03$. Thus, despite attempts to improve the effectiveness of mental strategies and to increase the sensitivity of priming measures in general, item-specific priming failed to develop in mental strategy groups, as in Experiment 2, but such priming was again evident for the no-instruction group, as in Experiment 1.

It should be noted that the performance advantage for old stimuli as shown by the no-instruction group, but not the mental strategy groups, is attributable to superior item-specific benefits (improvements from training stimuli to old stimuli during the test phase) in the no-instruction group, rather than to superior generalized benefits (improvements from training stimuli to new test stimuli) in the mental strategy groups. That is, subjects in the no-instruction group improved more from training stimuli to old test stimuli ($M = 7.12$ s for the no-instruction group, as compared with $M = 4.95$ s, 5.13 s, and 5.43 s, for concentrate, locomotive, and album groups, respectively). A preplanned comparison indicated that the superior item-specific improvement for the no-instruction group, as compared with the mental strategy groups, was reliable, $t(124) = 2.76$, $p < .01$. However, all groups improved in a similar fashion from training stimuli to stimuli that were new in the test phase ($M = 5.87$ s for the no-instruction group and $M = 4.55$ s, 5.15 s, and 5.47 s for concentrate, locomotive, and album groups, respectively). A preplanned comparison comparing the no-instruction group with the mental strategy groups supported this observation, $t(124) = 1.08$, $p < .29$. Thus, as noted, the evidence of priming in the no-instruction group, but not in the mental strategy groups, was related to superior item-specific benefits in the no-instruction group, as opposed to superior generalized benefits in the mental strategy groups.

Finally, it is noteworthy that there was no reliable difference across any of the groups in a measure of generalized skill development. Specifically, the improvement between performance in the training phase and the new items in the test phase did not reliably vary as a function of group, $F(3, 124) = 0.73$, $p < .53$, $MS_e = 6.76$. As in Experiment 2, the failure to find any benefit of mental strategy group on either generalized or item-specific memory performance is inconsistent with anecdotal claims about benefits for a perceptual–motor task with appropriate elaborative processing (metaphoric) strategies.

Explicit memory. The results from the explicit recognition memory test were similar to those of Experiment 2. That is, as shown in Table 3, subjects in the album group (.79) performed better than did subjects in the other groups on the recognition task (for locomotive, .59; for concentrate, .60; and for no-instruction, .54). The main effect of group was significant in a one-way, between-subjects ANOVA, $F(3, 124) = 13.42$, $p < .0001$, $MS_e = 0.028$. Post hoc Tukey comparisons confirmed that average recognition performance for the album group was reliably higher than the average performance for each of the remaining three groups. However, none of the other groups differed from each other. Individual z tests indicated that only the average recognition score for the album group was reliably above chance, $z = 3.96$, $p < .01$. Thus, elaborative processes that emphasized which stimuli were presented (album strategy) again resulted in superior explicit memory performance, and elaborative processes that emphasized how to do the pursuit rotor task (locomotive strategy) and perceptual processes (concentrate strategy) again resulted in performance that did not reliably differ from chance.

General Discussion

The primary goal of our investigation was to provide information regarding the role of distinct types of elaborative processing in both implicit and explicit perceptual–motor memory performance. On the basis of arguments from a transfer-appropriate processing framework, we assumed that elaborative processes that emphasized which specific stimuli were encountered would primarily facilitate explicit memory performance, whereas elaborative processes that emphasized *how* to perform the perceptual–motor task would primarily influence implicit-memory performance. On the other hand, according to the dual-process (dissociation) model, implicit and explicit memory performance are best distinguished by different processing levels. Hence, one should expect explicit memory performance to be primarily modulated by elaborative processes, whereas implicit memory performance should be relatively uninfluenced by distinct levels of elaborative processing and possibly be best under conditions that emphasize perceptual–integrative processes.

Despite our repeated attempts, the results fail to show a common reliance of explicit and implicit memory on elaborative processes. Elaborative processing conditions that emphasized which stimulus was stored (i.e., the album conditions in Experiments 2 and 3) consistently produced the highest level of explicit memory performance. Conversely, despite anecdotal claims about the benefits of elaborative (metaphoric) processing strategies for perceptual–motor tasks (Fleshman, 1984; Lessac, 1967), there was no evidence that any elaborative processing condition, including two that emphasized how to do the pursuit rotor task (stir condition in Experiment 2 and locomotive condition in Experiment 3), produced higher implicit memory performance than did any other condition (e.g., the concentrate or album conditions in Experiments 2 and 3). In fact, implicit memory, as reflected by item-specific priming (without corresponding above-chance explicit memory), was evident only when no instructions of any type were imposed (no-instruction groups in Experiments 1 and 3).

Thus, our results appear most consistent with the view that explicit and implicit memory performance in the perceptual–motor domain are regulated by qualitatively different types of processing modalities. (See also Heindel, Butters, & Salmon, 1988, for some evidence of a neuroanatomical dissociation between explicit and implicit memory performance, including information about a pursuit rotor task.) Specifically, the results indicate that explicit memory (recognition) performance for a perceptual–motor task appears to depend primarily on elaborative processes that individuate target events. Conversely, item-specific implicit perceptual–motor memory as reflected by priming appears to depend primarily on spontaneous or nonstrategic processes or both. Arguments for a dissociation approach are particularly strong on the basis of the present results because a condition that benefited explicit memory performance (album condition in Experiments 2 and 3), as compared with the no-instruction control (Experiment 3), resulted in depressed implicit memory performance. Although rarely reported in previous studies, similar findings were noted by Schacter and colleagues (Schacter et al., 1990, Experiment 2) in a study on memory for novel three-dimensional objects. In that study, elaborative encoding of the objects benefited explicit memory (recognition) performance for the objects but resulted in impaired implicit memory performance (priming on a task requiring possible–impossible object decisions). Schacter et al. (1990) concluded that implicit memory performance was impaired with the imposition of an (elaborative) encoding strategy because the strategy interfered with perceptual processing. Thus, the finding of a strategy that benefits explicit memory performance while disrupting implicit memory performance is not new to this literature.

Now consider our results within the specific dual-process model that motivated the present research (e.g., as originally proposed by Mandler and his colleagues; Graf et al., 1982; Mandler, 1979, 1980). For explicit memory, the findings are consistent with the suggestion that explicit memory performance depends on elaborative processes. However, on the basis of the present results, a caveat is necessary. Elaborative processes benefited explicit memory performance, but only under conditions in which these processes uniquely specified target events. Specifically, elaborative processing conditions that individuated target events (album conditions) consistently resulted in superior explicit memory performance, as compared with elaborative processing conditions that emphasized how to do the pursuit rotor task (stir and locomotive conditions). In fact, the elaborative conditions that emphasized how to do the task did not reliably yield above-chance explicit memory performance. Of course, this pattern is quite consistent with theoretical approaches emphasizing the critical role of individuating operations for episodic memory (Damasio, 1989; Tulving, 1972) and extends the importance of this factor beyond the verbal domain to the perceptual–motor domain.

Regarding implicit memory performance, our results appear inconsistent with the most straightforward predictions from the dual-process model. Specifically, according to this model, implicit memory depends on integrative or perceptual processes that occur whenever subjects are exposed to target stimuli. Thus, implicit memory performance should be similar across instructional conditions, or possibly superior, following conditions emphasizing perceptual processes (e.g., concentrate conditions). In the current experiments, neither of these predictions was confirmed. Implicit perceptual–motor memory manifestations (item-specific priming) developed only when mental strategies were not imposed. Therefore, the most straightforward explanation of our results for implicit memory is that it depends on spontaneous or nonstrategic processing, or both.

Of course, one might ask whether one can reconcile these results with the dual-process model. Perhaps this model can account for our findings, with a single qualifier. The qualifier is not related to domain (perceptual–motor vs. verbal), as might seem obvious, but is related to our use of novel stimuli compared with the use of familiar stimuli in previous studies supporting the dual-process model. That is, as suggested by this model, implicit memory phenomena (item-specific priming) depend on the integrative processing of perceptual fragments. Possibly, integrative processing requires full attentional allocation when novel stimuli, such as those we used, are presented, whereas full attentional allocation may not be as crucial for the familiar verbal stimuli typically used in the previous studies. The final piece of the argument is that imposed strategies essentially function as secondary tasks. According to this logic, priming should in fact occur when mental strategies are imposed and the stimuli are familiar to subjects, because the processes that support priming do not require full attentional allocation that might be disrupted by imposed strategies. In contrast, priming should not occur when mental strategies are imposed along with novel stimuli because, in this case, the perceptual processes that support priming require full attentional allocation and are disrupted when strategies are imposed.

Of course, this interpretation is post hoc. However, there are a series of findings in the literature that appear to support this interpretation. For example, there is clear evidence that attention plays a diminishing role as a function of practice for both verbal and nonverbal tasks. Performance decrements are anticipated with secondary loads in early phases of acquisition, whereas increasingly diminished decrements are anticipated in later phases (see, e.g., LaBerge & Samuels, 1974; Schneider & Fisk, 1982). More relevant to the present discussion are reports about the role of attention for implicit memory performance across varying acquisition levels. For example, according to a study by Nissen and Bullemer (1987), item-specific performance benefits (essentially priming) for a novel, repeated, 10-movement sequence were disrupted under secondary load conditions. Along the same lines, Ferraro, Balota, and Connor (1993) reported that individuals with Alzheimer's disease (subjects with well-documented attentional breakdowns; cf. Nestor, Parasuraman, & Haxby, 1991) also produce decreased item-specific priming in the Nissen and Bullemer Task. In contrast, priming for familiar verbal stimuli and for pictures of familiar objects is apparently unimpaired under secondary load conditions (Parkin, Reid, & Russo, 1990; Parkin & Russo, 1990). Moreover, priming of familiar representations also appears to be unimpaired in individuals with Alzheimer's disease (Balota & Duchek, 1991; Moscovitch, Winocur, & McLachlan, 1986).[6] The results across these studies imply that attention becomes increasingly less important for critical integrative processes to occur as acquisition level advances. Hence, at this level, our results may be viewed as still consistent with the dual-process model. For novel stimuli, perceptual processes that support priming require attentional allocation and are interfered with when strategies are imposed. For familiar stimuli, perceptual processes can occur even under secondary load conditions (e.g., imposed encoding instructions, wherein attentional allocation is somewhat disrupted). Of course, this explanation requires considerable and further investigation by using tasks beyond the pursuit rotor and others described here.

To summarize, it is possible to view our results as consistent with the original dual-process model. That is, it may be the case that perceptual–integrative processes are the crucial factor for implicit memory performance. For familiar stimuli, such as those used in most previous studies, such processes may occur with minimal attentional allocation and thus are not disrupted by the imposition of mental strategies. For novel perceptual–motor stimuli, such as those used in our study, the critical perceptual processes may require fuller allocation and are thus disrupted when mental strategies are imposed, resulting in impaired priming.

In conclusion, our results are consistent with a general dissociation approach to explicit and implicit memory and extend the dissociation approach beyond the verbal domain. Explicit perceptual–motor memory performance appears to depend on elaborative processes that individuate target stimuli. Implicit perceptual–motor memory performance for novel stimuli appears to depend on spontaneous or nonstrategic processes, or both. One goal of future research in this area should be a clearer understanding of the role of attentional allocation for priming with familiar and unfamiliar patterns.

[6] There is evidence that individuals with Alzheimer's disease (AD) do produce some deficit in priming as measured by stem-completion measures (see review by, Butters, Heindel, & Salmon, 1990). This indicates that AD individuals do produce breakdowns even in the priming of familiar representations such as words and pictures. There are two points to note here: First, it is possible that AD individuals produce the deficits in stem completion–type tasks because this task in general produces a high load on attentional resources. Second, Gross, Wilson, and Fox (1990) have recently reported preserved word-stem completion of semantically encoded information in AD individuals. When a breakdown in the priming of familiar representations occurs in a stem-completion task, it may be due to the possibility that AD individuals are less likely to fully encode the primes.

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