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Implicit and Explicit Memory for Novel Visual Objects in Older and Younger Adults

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Two experiments examined effects of aging on implicit and explicit memory for novel visual objects. Implicit memory was assessed with an object decision task in which subjects indicated whether briefly exposed drawings represented structurally possible or impossible objects. Explicit memory was assessed with a yes–no recognition task. On the object decision task, old and young subjects both showed priming for previously studied possible objects and no priming for impossible objects; the magnitude of the priming effect did not differ as a function of age. By contrast, the elderly were impaired on the recognition task. Results suggest that the ability to form and retain structural descriptions of novel objects may be spared in older adults.

Explicit memory refers to conscious recollection of previous experiences, as expressed on recall and recognition tests, whereas *implicit memory* refers to facilitations of performance, often referred to as priming effects, on tests that do not require any conscious or intentional retrieval of previous experiences (Graf & Schacter, 1985; Schacter, 1987). An already large and ever-growing body of research has demonstrated that explicit and implicit memory can be dissociated by numerous experimental manipulations and that implicit memory is often spared in brain-damaged amnesic patients with severe impairments in explicit remembering (for reviews, see Richardson-Klavehn & Bjork, 1988; Roediger, 1990; Schacter, 1987; Shimamura, 1986).

The explicit–implicit distinction is of considerable interest from the perspective of cognitive aging. Although it is well-known that age-related memory deficits can be observed on numerous explicit memory tests, a number of recent studies have indicated that age effects can be attenuated or even eliminated on various implicit memory tests (for review, see Graf, 1990; Howard, 1991; Light, 1991). Thus, for example, old and young subjects have shown comparable priming effects on tests of word completion (Light, Singh, & Capps, 1986; Howard, Fry, & Brune, 1991), word identification (Light & Singh, 1987), reading (Moscovitch, Winocur, & McLachlan, 1986), and picture naming (Mitchell, Brown, & Murphy, 1990). By contrast, age-related priming deficits have been documented in other experiments on some of the same tasks (cf. Chiarello & Hoyer, 1988; Davis et al., 1990; Hultsch, Masson, & Small, 1991). These latter findings are difficult to interpret, however, because they may well reflect "contamination" of implicit task performance by explicit retrieval strategies, strategies that are more beneficial to young than to old subjects (cf. Graf, 1990; Howard, 1991; Light, 1991; Schacter, Bowers, & Booker, 1989; Schacter, Kihlstrom, Kaszniak, & Valdiserri, in press).

Whatever the reasons for discrepancies among existing studies, it seems clear that a great deal remains to be learned about the nature and extent of implicit memory abilities in the elderly. In the present article, we extend research on implicit memory and aging into a previously unexplored domain: priming of novel, three-dimensional visual objects. We have developed an experimental paradigm for examining this issue in a series of recent studies (Cooper, Schacter, Ballesteros, & Moore, 1992; Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). The paradigm makes use of drawings that depict unfamiliar structures such as those displayed in Figure 1. Half of the drawings represent structurally possible objects that could exist in the three-dimensional world. The other half represent structurally impossible objects whose surfaces and edges contain ambiguities and inconsistencies that would prohibit them from existing as actual three-dimensional objects. Subjects initially study drawings of both types of objects for several seconds and are then given explicit, implicit, or both memory tests. Explicit memory is assessed with a standard yes–no recognition memory task in which studied and nonstudied objects are presented, and subjects indicate whether they remember studying an object previously. Implicit memory is assessed with an object decision task in which studied and nonstudied objects are flashed briefly (typically for 100 ms or less), and subjects decide whether each object is possible or impossible. Priming on this task is indicated by more accurate object decisions about studied than nonstudied drawings.

A number of experiments have shown that significant priming is observed on the object decision task and have delineated

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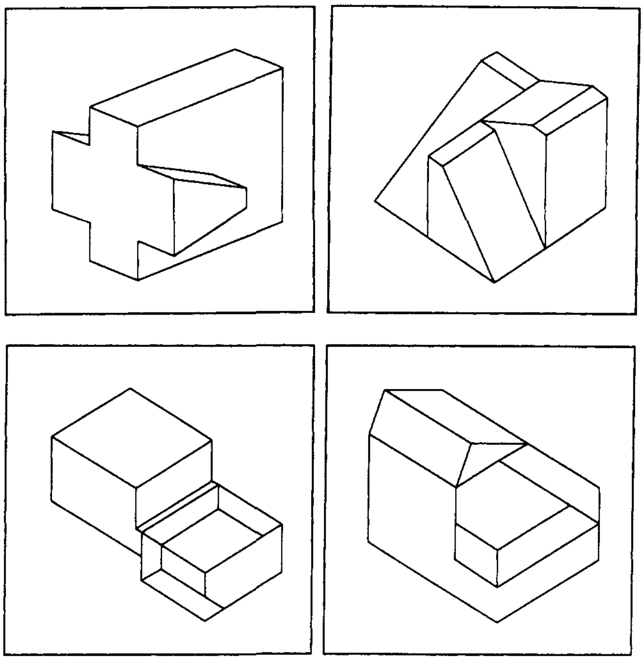

Figure 1. Sample of objects used in our experiments. (The drawings in the upper row depict possible objects that could exist in three-dimensional form. The drawings in the lower row depict impossible objects that contain structural violations that would prohibit them from actually existing in three-dimensional form. See text for further explanation.)

several of its properties. Specifically, our studies indicate that object decision priming (a) is observed for possible but not for impossible objects, (b) depends on encoding information about the global structure of the object at the time of initial study, (c) is not increased—and may even be reduced—by elaborative study tasks that greatly enhance explicit memory, and (d) is relatively unaffected by study-to-test changes in the size and left–right reflection of target objects, even though such changes impair recognition memory significantly (Cooper et al., 1992; Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, et al., 1991), but is eliminated by study-to-test changes in picture plane orientation of objects (Cooper, Schacter, & Moore, 1991). In addition, brain-damaged patients with explicit memory disorders have shown normal priming on the object decision task (Schacter, Cooper, Tharan, & Rubens, 1991).

There are several reasons why the object decision paradigm is appropriate for studying cognitive aging. First, most previous research on priming and aging has used verbal materials, such as words or paired associates; there have been few studies that used nonverbal materials. In one such study, Mitchell et al. (1990) found that elderly subjects show intact priming of latency to name familiar objects despite impaired recognition memory. However, this task involves a large verbal component. Russo and Parkin (1991) have reported impaired priming in the elderly on a picture fragment completion task, although the authors acknowledged that the impairment may be attributable to explicit rather than implicit memory deficits. Given these contrasting results, further research on priming of nonverbal information in the elderly is clearly needed (cf. Schacter, Delaney, & Merikle, 1990). Note also that Howard and Howard (1992) have reported evidence of intact implicit learning of nonverbal information in elderly adults using a different type of task that involves learning to respond to a repeated spatiotemporal sequence of lights (e.g., Nissen & Bullemer, 1987).

A second advantage of the object decision paradigm is that it allows us to address the important question of whether priming effects in the elderly depend on, or reflect the activation of, preexisting memory representations of target items. Because familiar words and objects are represented in memory before the experiment, it can be argued that priming in experiments using such materials reflects the temporary activation of old, preexisting knowledge. Our possible and impossible objects, however, do not exist in memory before the experiment, so priming is necessarily based on newly formed representations. As noted earlier, Howard and Howard (1992) have shown that elderly subjects can learn a novel spatiotemporal sequence. Evidence bearing on priming of new versus old information in the elderly has been reported in experiments by Howard et al. (1991) that examine implicit memory for newly acquired associations between unrelated words. Using a paradigm developed by Graf and Schacter (1985; Schacter & Graf, 1986), they found that elderly subjects showed normal priming of new associations under some experimental conditions and impaired priming of new associations under other conditions. Thus, the status of priming of novel information in the elderly requires further investigation and clarification.

A third reason for using the object decision paradigm with elderly adults is that we have developed some relatively well-specified ideas about the locus of the observed priming effects. On the basis of the findings that object decision priming requires encoding of global object structure, does not benefit from semantic encoding, and transfers across study–test changes in object size and reflection, we have argued that such priming is mediated by a structural description system (cf. Riddoch & Humphreys, 1987). The structural description system is a subsystem of a more general perceptual representation system (Schacter, 1990, 1992; Tulving & Schacter, 1990) that is specialized for representing and retrieving information about the global form and structure of objects. By hypothesis, the structural description system does not represent information about an object's associative and functional properties and is distinct from the episodic memory system that underlies explicit recollection of a specific encounter with an object. According to this view, priming of possible objects on the object decision task reflects the establishment, at the time of study, of novel structural descriptions that preserve information about global relations among object parts. As noted earlier, our experiments have consistently failed to produce significant priming of impossible objects (e.g., Schacter, Cooper, Delaney, et al., 1991). This finding may indicate that it is difficult to form a representation of the global structure of an impossible object (cf. Hochberg, 1968).

Independent evidence for the existence of a structural description system has been provided by studies showing that brain-damaged patients with object-processing deficits have relatively intact access to structural knowledge about objects, despite severely impaired access to knowledge of their functional and associative properties (cf. Riddoch & Humphreys, 1987; Warrington, 1975, 1982; Warrington & Taylor, 1978). Moreover, evidence from patient studies, as well as from single-cell recordings and lesion experiments in nonhuman primates, suggests thatregions of inferior temporal cortex constitute an important neuroanatomical basis of the structural description system (for review, see Plaut & Farah, 1990). We have thus suggested that this brain region plays a key role in object decision priming (Cooper et al., 1992; Schacter, Cooper, Tharan, & Rubens, 1991). Therefore, if intact object decision priming is observed in elderly adults, it could be argued that aging spares the ability of this system to form new representations of the global structure of unfamiliar objects.

Experiment 1

To investigate object decision priming in the elderly, we used the basic procedure and materials described by Schacter, Cooper, and Delaney (1990). Old and young subjects were initially exposed to a series of possible and impossible figures such as those in Figure 1, and judged whether each object appeared to be facing primarily to the left or to the right. The left–right encoding task was used because it has produced reliable evidence of priming in previous studies (Cooper et al., 1992; Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, et al., 1991; Schacter, Cooper, Tharan, & Rubens, 1991). Following this study phase, subjects were given either an object decision or yes–no recognition task. Finally, subjects who were given the recognition task first were given an object decision task, and subjects who were given the object decision task first were then given a recognition task.

Method

Subjects. Sixteen elderly and 16 young subjects took part in the experiment. All subjects were paid $10 for their participation. Elderly subjects were recruited through sign-up sheets and advertisements that were posted in local libraries, senior centers, and newsletters on the University of Arizona campus. Young subjects were recruited with sign-up sheets that were posted at the University of Arizona.

All subjects were native English speakers who performed normally on a reading test in which they read aloud from printed passages in standard book type and passed with 80% or greater accuracy a speech discrimination test consisting of repeating words and phrases spoken by the experimenter from the Boston Diagnostic Aphasia Examination Repetition subtest (Goodglass & Kaplan, 1983). In addition, all subjects were individually interviewed to rule out those with a history of any of the following: alcoholism or substance abuse; recent myocardial infarction or chronic cardiovascular disease; cerebrovascular accident; present or previous treatment for acute or chronic psychiatric illness; syphilis; brain damage sustained earlier from a known cause (e.g., hypoxia); chronic renal, hepatic, pulmonary, or endocrine disease; uncontrolled chronic hypertension; primary systemic illness; metabolic or drug toxicity; primary degenerative brain disorders (e.g., Alzheimer's, Parkinson's, or Huntington's disease); and cancer. In addition, no subjects were admitted to the experiment who had a score of 11 or greater on the Geriatric Depression Scale (Scogin, 1987; Yesavage et al., 1983) or who had subscale scores that were two or more standard deviations above the mean for older adults on the Brief Symptom Inventory (Hale, Cochran, & Hedgepeth, 1984).

Mean age of elderly subjects was 69.4 years (*SD* = 6.4, range = 63–81), whereas mean age of young subjects was 18.2 years (*SD* = 0.54, range = 17–19). Elderly subjects had on average 15.3 years of education (*SD* = 2.4), whereas young subjects had on average 12.3 years of education (*SD* = 0.58). On the Wechsler Adult Intelligence Scale—Revised (WAIS–R), old subjects scored higher than did young on the two subscales that were administered: Information (old = 24.6, *SD* = 2.8; young = 19.2, *SD* = 5.0) and Vocabulary (old = 62.5, *SD* = 6.2; young = 49.9, *SD* = 7.8). By contrast, on the Wechsler Memory Scale—Revised (WMS–R), old subjects scored more poorly than young on the two subtests that were administered: Logical Memory (old = 36.9, *SD* = 6.8; young = 55.2, *SD* = 6.5) and Visual Reproduction (old = 61.9, *SD* = 6.3; young = 75.9, *SD* = 3.4).

Materials, design, and procedure. The target materials were the 20 possible and 20 impossible objects used by Schacter, Cooper, and Delaney (1990). The objects had been selected on the basis of an earlier study with young subjects that indicated that (a) there was relatively high agreement about whether they were possible or impossible when subjects were given unlimited time to classify them and (b) unprimed performance with brief presentation (i.e., 100 ms) was approximately 60%–65% correct, thus allowing room for potential priming effects to be observed.

The object drawings were divided randomly into two sets, A and B, that each contained 10 possible objects and 10 impossible objects. Each subject studied either Set A or Set B and was later tested on both object sets. The drawings were presented for study and test by a Compaq 386 Deskpro computer on the screen of a 12-in Princeton Ultrasync Monitor. They subtended a mean visual angle of 18.4° when viewed from 45 cm. The drawings were presented in medium resolution and appeared white against a uniform dark-gray background.

The main experimental design was a 2 (age) × 2 (test order) × 2 (object type) × 2 (item type) mixed factorial. The lst two variables—old versus young subjects and object decision test first versus recognition test first—were between-subjects factors. The latter two variables—possible versus impossible objects and studied versus nonstudied objects—were within-subjects variables. The experiment was completely counterbalanced so that drawings from Set A and Set B appeared equally often as studied and nonstudied objects for both age groups and in both test orders.

For all subjects, the first phase of the experiment involved performing the left–right study task. Subjects were told that a series of drawings of unfamiliar structures would appear on the computer monitor and that their task was to judge whether each drawing appeared to be facing primarily to the left or to the right. They were further informed that the drawings were not as simple as they might appear, so that it was important to use the full 5 s to make the left–right judgment. Each object was exposed for 5 s on the computer screen, preceded by a fixation point. The task began with presentation of 5 practice items, followed by presentation of the 10 possible and 10 impossible target items in a different random order for each subject.

Half of the subjects in each age group were then given the object decision task, whereas the other half were given the recognition task. For the object decision test, subjects were instructed that they would be exposed to a series of briefly displayed drawings. They were informed that some of the drawings represented valid, possible three-dimensional objects that could exist in the real world, whereas other drawings represented impossible figures that could not exist as actual objects in the real world. It was explained that their task was to decide whether each object was possible or impossible. Several practice objects of each type were then shown to the subjects. They were informed that all possible objects must have volume and be solid, that every plane on the drawing represents a surface on the object, that all surfaces can face in only one direction, and that every line on the drawing represents an edge on the object. The experimenter explained the impossibilities in sample objects and answered questions as needed.

Subjects were also instructed to respond with a personal computer

(PC) mouse that they controlled with their preferred hand; they were told to press the left key when they thought that the object was possible and the right key when they thought that the object was not possible. Administration of instructions required about 2 min.

The object decision test then began with presentation of 10 practice items, 5 that had appeared as practice items at study and 5 that were new, followed by the 40 critical drawings in a different random order for each subject. Each drawing was presented for 100 ms, preceded by a fixation point and followed by a darkened screen.

For the recognition test, subjects were told that they would be shown a further series of drawings, some of which had just been exposed during the encoding task, and some of which had not been exposed previously. Subjects were instructed to use the mouse and to press the left key if they remembered seeing the object during the encoding task and the right key if they did not remember seeing the object previously. As on the object decision task, 10 practice drawings (5 old and 5 new) were presented before the 40 critical drawings, and about 2 min elapsed between the end of the study list and the appearance of the first critical drawing. Objects remained on the computer screen for 6 s until subjects made their recognition response.

After the conclusion of the initial tests, subjects who had been given the object decision test were given the recognition test, and subjects who had been given the recognition test were given the object decision task. Instructions and procedure were the same as described previously. For subjects who were given the recognition test after the object decision test, and hence had received some exposure to all objects, it was emphasized that a yes response should be made only when they remembered seeing a drawing during the study task. After the conclusion of testing, all subjects were debriefed about the nature and purpose of the experiment.

Results

Object decision. Table 1 displays the proportion of correct object decisions by young and old subjects. Several points about these data should be noted. First, the object decision task was quite difficult for the old subjects: Baseline object decision performance for nonstudied items was at the chance level for elderly adults (.48), whereas it was over .60 for young subjects. Second, and more important, both old and young subjects showed priming of possible but not of impossible objects, and the overall magnitude of the observed priming effect was virtually identical in the two groups. Third, comparison of performance in the object decision first and second conditions indicated that the appearance of an item on the recognition test did not produce consistent priming in either group, although there were trends for test priming in individual conditions.

An analysis of variance (ANOVA) revealed a main effect of item type (studied vs. nonstudied), $F(1, 28) = 4.88$ ($MS_e = .027$, $p < .05$), indicating that object decision accuracy was higher for studied than for nonstudied drawings, and a significant interaction between item type and object type (possible vs. impossible), $F(1, 28) = 4.50$ ($MS_e = .024$, $p < .05$), indicating that priming was observed for possible but not for impossible objects. A significant main effect of age was also documented, $F(1, 28) = 10.14$ ($MS_e = .076$, $p < .01$), showing that the object decision task was more difficult for the old than the young. More important, however, the interaction between age and item type did not approach significance, $F(1, 28) < 1$, thus confirming that old and young showed similar amounts of priming, and age did not enter into any other significant interactions (all Fs < 2.05). The main effect of test order was not significant, $F(1, 28) < 1$, nor did test order enter into any significant interactions (all Fs < 2.05).

The foregoing analyses suggest that both old and young subjects showed significant priming for possible objects. To test this more directly, we performed separate 2 × 2 ANOVAs for old and young on the results for possible objects only, with item type (studied vs. nonstudied) as a within-subjects factor and test order as a between-subjects factor. For the elderly, the ANOVA showed a significant main effect of item type, $F(1, 14) = 4.81$ ($MS_e = .026$, $p < .05$), and no other effects (Fs < 1). The same pattern was observed for the young, except that the main effect of item type was only marginally significant, $F(1, 14) = 4.16$ ($MS_e = .027$, $p = .06$).

Although the foregoing analyses appear to indicate that object decision priming is spared in the elderly, the fact that baseline levels of performance differed in the old and young suggests the need for some interpretive caution. To address the issue, we performed an additional analysis in which we subtracted the proportion of correct object decisions for nonstudied possible and impossible objects from the proportion of correct object decisions for studied possible and impossible objects. An ANOVA on these priming scores revealed nonsignificant main effects of age and test order and a nonsignificant Age × Test Order interaction (all Fs < 1). Thus, even with baseline differences subtracted, there was no evidence of an age-related deficit in object decision priming. It is also worth noting that priming was intact in the elderly when it was analyzed with an absolute score, as discussed earlier (i.e., studied minus nonstudied items), or as a proportional score. With respect to the latter measure, the elderly showed about a 24% increase in object decision accuracy for studied relative to nonstudied possible objects (i.e., .67 vs. .54) and a 15% increase overall (i.e., .55 vs. .48). Young subjects showed about a 19% increase for studied

Table 1
Object Decision Performance for Studied and Nonstudied Objects as a Function of Age, Object Type, and Test Order in Experiment 1

Test order/ item type	Old P	Old I	Old *M*	Young P	Young I	Young *M*
First						
S	.65	.43	.54	.71	.63	.67
NS	.49	.46	.48	.61	.56	.59
S − NS	.16	−.03	.06	.10	.07	.08
Second						
S	.69	.40	.55	.80	.63	.71
NS	.60	.36	.48	.66	.69	.68
S − NS	.09	.04	.07	.14	−.06	.03
M						
S	.67	.42	.55	.76	.63	.70
NS	.54	.41	.48	.64	.63	.64
S − NS	.13	.01	.07	.12	.00	.06

Note. S and NS cell entries indicate proportion correct object decisions; S − NS is the priming score for each condition. P = possible objects; I = impossible objects; S = studied objects; NS = nonstudied objects.

relative to nonstudied possible objects (.76 vs. .64) and a 10% increase overall (.70 vs. .64).

Recognition. Table 2 shows data from the yes–no recognition test, which are displayed in terms of hits (yes responses to studied objects), false alarms (yes responses to nonstudied objects), and corrected recognition scores (hits − false alarms). In contrast with their normal levels of priming, elderly adults' explicit memory for novel objects was considerably less accurate than that of the young, as indicated most clearly by the corrected recognition scores. Although the hit rates for the elderly were in some conditions quite comparable with those of the young, they showed consistently elevated false-alarm rates, thus producing impaired recognition performance. Corrected recognition scores for possible objects were higher than for impossible objects in both old and young, and performance was somewhat worse for both age groups when the recognition test was given after the object decision test than when it was given first.

An ANOVA was performed on the corrected recognition scores of old and young subjects. The analysis revealed significant main effects of age, $F(1, 28) = 8.34$ ($MS_e = .094$, $p < .01$), and object type, $F(1, 28) = 5.57$ ($MS_e = .038$, $p < .05$), and a nonsignificant main effect of test order, $F(1, 28) = 1.04$ ($MS_e = .094$). No interactions approached significance (all $Fs < 1$).

Discussion

The major result of Experiment 1 was that elderly adults showed normal implicit memory for novel objects on the object decision test: Old and young both exhibited priming for possible objects and no priming for impossible objects. The magnitude of the priming effect was virtually identical in the old and young whether it was assessed in terms of absolute or proportional increases relative to baseline. By contrast, explicit memory for novel objects was impaired in elderly adults.

Table 2
Recognition Performance for Studied and Nonstudied Objects as a Function of Age, Object Type, and Test Order in Experiment 1

Test order item type	Old P	Old I	Old *M*	Young P	Young I	Young *M*
First						
S	.75	.54	.65	.68	.70	.69
NS	.46	.44	.45	.20	.34	.27
S − NS	.29	.10	.20	.48	.36	.42
Second						
S	.56	.49	.53	.68	.56	.62
NS	.38	.44	.41	.33	.24	.29
S − NS	.18	.05	.12	.35	.32	.33
M						
S	.66	.52	.59	.68	.63	.66
NS	.42	.44	.43	.27	.29	.28
S − NS	.24	.08	.16	.41	.34	.38

Note. The corresponding proportions for NS are false-alarm rates, or proportion of nonstudied objects called old. The corresponding proportions for S are hit rates or proportion of studied objects called old. P = possible objects; I = impossible objects; S = studied objects; NS = nonstudied objects.

The overall pattern of results is consistent with the idea that cognitive aging spares the ability to form novel structural descriptions of unfamiliar objects and that age-related deficits in memory for novel objects are confined to explicit memory. However, each of the age groups in Experiment 1 was composed of a relatively small number of subjects ($n = 16$), and it is conceivable that our failure to detect age differences in priming is attributable to a small sample size. This possibility seems unlikely, because (a) there were no age differences in magnitude of priming (as opposed to a trend that did not reach significance because of small sample size) and (b) the sample size was adequate to allow detection of significant differences in recognition performance. Nevertheless, it would be desirable to examine object decision performance with a more sensitive experiment that includes larger groups of old and young subjects.

Another potential difficulty with Experiment 1 was that the impossible objects we used, which were drawn from our first study (Schacter, Cooper, & Delaney, 1990), were less than ideal: When pilot subjects in Schacter, Cooper, and Delaney (1990) were given unlimited time to classify drawings as possible or impossible there was only 87% agreement about the impossible objects, compared with 99% agreement for possible objects. Moreover, the priming data for this set of impossible objects showed marked fluctuation across experimental conditions (Schacter, Cooper, & Delaney, 1990), and some fluctuations of this kind can be noted in Table 1. We have subsequently developed a set of impossible objects with 99% intersubject agreement that yields more stable patterns of results (Schacter, Cooper, & Delaney et al., 1991). It would be desirable to determine whether elderly adults exhibit normal priming when these stimuli are used.

We attempted to address the foregoing issues by changing several features of Experiment 1. To determine whether age differences in priming could be observed with a more sensitive experimental design, we doubled our sample size to include 32 subjects in each age group and gave all subjects the object decision test before the recognition test. We included this latter change because there were some (nonsignificant) trends for test priming in Experiment 1, and we wanted to provide as strong a test as possible of the hypothesis that older adults show normal implicit memory for objects that appeared only during the study episode. To reduce and, we hoped, eliminate any problems that might be attributable to the object set, we replaced the impossible objects from Experiment 1 with the set developed by Schacter, Cooper, Delaney, et al. (1991). Finally, we also used a briefer object decision exposure duration for young subjects (50 ms) and a longer one for old subjects (250 ms) in an attempt to produce more closely comparable levels of baseline performance in the young and old.

Experiment 2

Method

Subjects. Thirty-two old and 32 young subjects participated in the experiment. They were recruited and paid in the same manner described for Experiment 1. In addition, inclusion criteria for the elderly were the same as described previously for Experiment 1.

Mean age of elderly adults was 70.9 years (SD = 7.0, range = 60–81), whereas mean age of young subjects was 19.9 years (SD = 1.8, range = 17–25). Elderly subjects had on average 13.9 years of education (SD = 2.9), and young subjects had on average 13.8 years of education (SD = 1.4). On the WAIS–R, old subjects scored slightly higher than young on the Information subscale (old = 22.5, SD = 3.6; young = 21.9, SD = 3.1) and the Vocabulary subscale (old = 56.0, SD = 8.8; young = 55.8, SD = 6.6). On the WMS–R, old subjects scored more poorly than did young subjects on both Logical Memory (old = 39.8, SD = 7.2; young = 57.5, SD = 5.4) and Visual Reproduction (old = 56.7, SD = 7.7; young = 64.8, SD = 2.8).

Materials, design, and procedure. All aspects of materials, design, and procedure in Experiment 2 were identical to Experiment 1, with the following exceptions: With respect to materials, the impossible objects were the 20 used and described by Schacter, Cooper, and Delaney et al. (1991), with 99% agreement rates during unlimited viewing. Schacter, Cooper, and Delaney et al. (1991, Experiment 4) also equated possible and impossible objects for overall size, whereas the objects used in Experiment 1 were not systematically equated for size. We used the size-equated objects in this experiment.

With respect to design and procedure, we used the same left–right encoding task as in Experiment 1. In Experiment 2, however, subjects were given two exposures to the study list and hence performed the left–right judgment task twice for each object. In a previous study with young subjects, it was found that number of study exposures did not affect the magnitude of priming on the object decision task. The target objects were presented in different random orders on the two study trials. On the object decision test, drawings were exposed for 250 ms to elderly adults and 50 ms to young subjects. For all subjects, the object decision test was given before the recognition test.

Results

Object decision. Table 3 displays the results of the object decision task. The data for nonstudied items indicate that overall baseline performance for elderly subjects remained lower than for the young. Nevertheless, elderly adults still showed robust priming. Indeed, the absolute magnitude of priming for possible objects was actually somewhat larger in the old (.17) than in the young (.09). However, the elderly also showed a trend for negative priming of impossible objects—their object decision performance was .06 less accurate for studied than nonstudied objects—whereas the young showed a weak trend for priming of impossible objects. Thus, combined across possible and impossible objects, the absolute magnitude of the priming effect (.06) was identical in old and young subjects.

Table 3
Object Decision Performance for Studied and Nonstudied Objects as a Function of Age and Object Type in Experiment 2

	Old			Young		
Item type	P	I	*M*	P	I	*M*
S	.60	.47	.54	.75	.65	.70
NS	.43	.53	.48	.66	.61	.64
S – NS	.17	–.06	.06	.09	.04	.06

Note. S and NS cell entries indicate proportion correct object decisions; S – NS is the priming score for each condition. P = possible objects; I = impossible objects, S = studied objects; NS = nonstudied objects.

Table 4
Recognition Performance for Studied and Nonstudied Objects as a Function of Age and Object Type in Experiment 2

	Old			Young		
Item type	P	I	*M*	P	I	*M*
S	.64	.64	.64	.86	.66	.76
NS	.41	.47	.44	.31	.29	.30
S – NS	.23	.17	.20	.55	.37	.46

Note. The corresponding proportions for NS are false-alarm rates, or proportion of nonstudied objects called old. S – NS is the corrected recognition score for each condition. The corresponding proportions for S are hit rates or proportion of studied objects called old. P = possible objects; I = impossible objects; S = studied objects; NS = nonstudied objects.

An ANOVA revealed a main effect of item type (studied vs. nonstudied), $F(1, 62) = 8.06$ ($MS_e = .031$, $p < .01$), confirming that overall object decision accuracy was increased by study-list exposure. There was also an interaction of Item Type × Object Type (possible vs. impossible), $F(1, 62) = 13.18$ ($MS_e = .024$, $p < .001$), confirming that priming was observed for possible but not for impossible objects. A main effect of age was observed, $F(1, 62) = 31.79$ ($MS_e = .050$, $p < .001$), indicating that the object decision task was generally more difficult for the old than the young. More important, the Age × Item Type interaction was negligible ($F < 1$), thereby indicating that the overall magnitude of the priming effect did not differ in old and young. However, there was an unexpected three-way interaction of Age × Object Type × Item Type, $F(1, 62) = 6.64$ ($MS_e = .024$, $p < .05$). The interaction reflects the fact that elderly adults showed more priming for possible objects than did the young, whereas the old showed a trend for negative priming of impossible objects that was not observed in the young.

We performed t tests to determine which of the priming effects were individually significant. Both old, $t(31) = 3.58$, and young, $t(31) = 2.46$, showed significant priming for possible objects ($p < .05$), whereas the apparent trends for negative priming of impossible objects in the old, $t(31) = 1.14$, and positive priming of impossible objects in the young, $t(31) = 0.98$, both failed to achieve significance. Thus, although the three-way interaction may indicate some differences between patterns of priming in old and young, it is important to emphasize that the overall accuracy of object decision performance was increased similarly by study-list exposure in old and young.

Because baseline differences between old and young were observed, we performed an additional analysis in which we subtracted the proportion of correct object decisions for nonstudied possible and impossible objects from the proportion of correct object decisions for studied possible and impossible objects. No age differences were observed ($t < 1$). In addition, it is worth noting that, as in Experiment 1, elderly subjects exhibited normal levels of priming whether absolute or proportional priming scores are considered.

Recognition memory. The recognition data, displayed in Table 4, are relatively clear-cut: Elderly adults showed less accurate explicit memory, as indicated by corrected recognition scores, than did the young for both possible and impossible objects. Elderly subjects' hit rate was depressed and false-alarm rate was elevated relative to young subjects in all conditions, although hit rates differed only slightly for impossible objects. An ANOVA was performed on the corrected recognition scores and revealed a highly significant effect of age, $F(1, 62) = 20.87$ ($MS_e = .119$, $p < .001$), and a significant main effect of object type, $F(1, 62) = 7.95$ ($MS_e = .063$, $p < .01$). The Age × Object Type interaction was not significant, $F(1, 62) = 1.61$ ($MS_e = .063$).

General Discussion

In two experiments, elderly adults exhibited spared priming of novel objects despite impaired explicit memory for the same objects. Priming in the elderly, as in the young, was observed for possible but not for impossible objects. Our data thus extend findings of preserved implicit memory abilities in elderly adults to the domain of novel three-dimensional objects, and they confirm previous reports that the elderly can show implicit memory for newly acquired information without a preexisting memory representation (Howard et al., 1991; Howard & Howard, 1992).

These conclusions must be qualified to some extent by the lower levels of baseline object decision performance in old than young subjects in both experiments; it would be desirable to find intact object decision priming under conditions in which baseline performance rates are statistically indistinguishable between older and younger subjects. As noted earlier, however, the elderly showed normal priming using both absolute and proportional measures. Nevertheless, the fact that older adults' baseline object decision performance was at chance levels in both experiments, whereas young subjects consistently performed at above-chance levels for nonstudied items, raises the possibility that the two groups may have performed the object decision task differently. For example, young subjects may have based their responses on access to specific information about object structure, whereas the elderly may have responded more on the basis of global familiarity with an object, tending to call an object possible when it seemed familiar.

Responding on the basis of global familiarity would tend to produce positive priming of possible objects and negative priming of impossible objects. The three-way interaction of Age × Item Type × Object Type noted in Experiment 2 is consistent with this hypothesis. However, the difficulty with this idea is that elderly adults showed an entirely normal priming effect in both experiments even when object decision performance was collapsed across possible and impossible objects—that is, they showed a normal increase in the accuracy of object decision performance. If they had been responding on the basis of global familiarity, there should have been a reduced increase in the overall accuracy of object decision performance for studied items.

Another way to address this issue is to examine the relation between object decision and recognition performance in the old and young. More specifically, in previous research we found that priming of possible objects exhibits stochastic independence from recognition memory for the same objects—that is, the probability of making a correct object decision is uncorrelated with the probability of making a correct recognition judgment (Schacter, Delaney, & Merikle, 1990). Stochastic independence between priming and explicit memory has been observed in a variety of experimental situations (cf. Hayman & Tulving, 1989; Hintzman & Hartry, 1990; Tulving, Schacter, & Stark, 1982). With respect to the present data, if elderly subjects rely more on familiarity than do the young to make object decisions, we might expect them to show dependence between priming and recognition under conditions in which young subjects show stochastic independence.

We examined the relation between object decision and recognition performance in Experiments 1 and 2, focusing solely on studied possible objects (because only these objects showed priming). To assess independence–dependence between priming and recognition, we used Yule's *Q*, a special case of Goodman and Kruskal's (1954) gamma correlation that applies to the analysis of data from 2 × 2 contingency tables (see Hayman & Tulving, 1989). *Q* measures the strength of the relation between two variables and can vary from −1 (negative association) to +1 (positive association), with 0 reflecting complete independence. We constructed 2 × 2 tables in which each cell corresponded to one of the four possible joint outcomes of subjects' responses to particular items on the object decision and recognition tests: correct on both tests, correct on object decision and incorrect on recognition, incorrect on object decision and correct on recognition, or incorrect on both tests. We then computed *Q* values using procedures outlined by Hayman and Tulving.

In Experiment 1, we performed these analyses separately for the recognition-first and object-decision-first conditions. When the recognition test was given first, we observed independence between recognition and object decision for both old subjects, $Q = +.07$, $\chi^2(1, N = 80) < 1$, and young subjects, $Q = +.02$, $\chi^2(1, N = 80) < 1$, in conformity with previous findings in recognition-first test conditions (Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, et al., 1991). By contrast, when the object decision test was given first, young subjects showed significant ($p < .01$) dependence, $Q = +.59$, $\chi^2(1, N = 80) = 7.28$, and old subjects showed a similar, albeit nonsignificant, trend for dependence, $Q = +.34$, $\chi^2(1, N = 80) = 2.02$. In Experiment 2, where the object decision test was always given before the recognition test, significant dependence was observed for the old, $Q = +.27$, $\chi^2(1, N = 320) = 4.75$, and young, $Q = +.45$, $\chi^2(1, N = 320) = 8.22$.

The independence between object decision and recognition performance in the recognition-first condition replicates earlier findings with young subjects and extends them to the elderly. However, the consistent evidence for dependence in the object-decision-first condition is somewhat puzzling. A rather similar pattern of results was reported by Tulving et al. (1982), who found independence between recognition and priming on a word fragment completion test when the recognition test was given first, but observed dependence between the two tasks when the fragment completion test was given first. The latter result was attributed to the fact that subjects who completed a fragment correctly received an additional exposure to it, thereby increasing the likelihood of subsequent recognition. In our study, however, a correct response on the object decision task did not result in an extra exposure to the object.

It is thus not entirely clear how to explain the asymmetrical pattern of dependence–independence that we observed. Analyses of stochastic independence involve a variety of complex issues (cf. Hayman & Tulving, 1989; Hintzman & Hartry, 1990; Shimamura, 1985), and further exploration of this asymmetry would require careful attention to these issues. The important point for the present purposes, however, is that the observed patterns of independence and dependence were quite similar in old and young. Thus, the contingency analyses do not support the idea that old subjects relied on a different kind of information to make object decisions than did the young.

Because the baseline performance of elderly adults was lower than that of the young subjects, we cannot rule out unequivocally the possibility that elderly adults rely more on familiarity and less on access to information about object structure than do the young when making object decisions; the matter clearly warrants further investigation. It should also be noted, however, that the low level of baseline object decision performance by elderly subjects creates problems for any attempt to account for preserved priming and impaired recognition in terms of task difficulty. That is, it is often tempting to argue that demonstrations of impaired explicit memory and preserved implicit memory in elderly adults indicate that explicit tasks are in some general sense more difficult than implicit tasks and are thus disproportionately affected by a general cognitive impairment associated with aging (cf. Light, 1991; McDowd & Craik, 1988; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). However, given that the object decision task was quite difficult for elderly adults—so difficult that their overall baseline performance was at chance levels—one cannot readily appeal to an easy implicit task as the basis for preserved priming. Instead, it is necessary to put forward hypotheses about specific processes or systems that are spared or impaired by cognitive aging.

As noted earlier, we have argued that object decision priming depends to a large extent on the structural description system, a perceptual representation subsystem that handles information about the global form and structure of objects independent of their associative and functional properties and that may depend critically on regions of inferior temporal cortex (Cooper et al., 1992; Schacter, 1990, 1992; Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, & Delaney, et al., 1991; Schacter, Cooper, Tharan, & Rubens, 1991). Explicit memory for objects and other materials, by contrast, requires an episodic or declarative memory system that encodes and retrieves multiple kinds of information (e.g., contextual, semantic, or perceptual) that render an object distinctive and likely depends on limbic structures, such as the hippocampus, as well as regions of frontal cortex (cf. Schacter, 1987; Squire, 1987; Tulving, 1983). Thus, one possible interpretation of the present results is that the ability of the structural description system to compute new representations of unfamiliar objects is spared by aging, whereas the ability of the episodic–declarative system to link these representations to contextual information, or to allow conscious access to them, is impaired by aging.

Consider first the possibility that a spared structural description system underlies object decision priming in the elderly. This result is consistent with the finding that older adults showed intact priming of possible objects, as well as the finding that they showed no priming of impossible objects. As noted earlier, we have suggested that lack of priming for impossible objects reflects computational constraints on the structural description system, that is, the difficulty of representing the global shape of an impossible object. To the extent that object decision priming in the elderly depends on the structural description system, it should be subject to the same constraints as are observed in young adults. However, the fact that elderly adults' baseline performance on the object decision task was less accurate than that of the young raises the possibility that the structural description system is not entirely spared by aging; as noted earlier, the elderly might tend to rely more on global familiarity and less on access to structural information when making object decisions.

Alternatively, because object decisions are based on extremely brief stimulus exposures, older adults' poor baseline performance may be attributable to a more general problem of slowed information processing (Cerella, 1985; Salthouse, 1985) that affects a variety of systems, impairing performance on a range of tasks that involve brief stimulus exposures. By this latter view, the structural description system would be subject to the same sort of slowing that most other perceptual–cognitive systems are but is otherwise intact and computes novel structural descriptions normally.

Although we cannot settle the issue on the basis of available data, there is some evidence suggesting that elderly adults have specific difficulties representing the three-dimensional structure of objects. Cerella, Milberg, and Plude (1991) found that elderly subjects performed poorly on a pattern perception task that required discriminating among objects on the basis of their three-dimensional structure, but performed normally on a similar task that involved processing of two-dimensional features. They suggested that the elderly form a "low resolution" three-dimensional model of target objects. These observations raise the possibility that the structural description system is not entirely spared by aging and that a specific impairment in this or some similar system contributes to the elderly's low level of baseline performance on the object decision task.

If this line of reasoning is correct, it immediately raises the question of why the elderly showed normal priming on the object decision task. One possibility is that the left–right encoding task constrains processing sufficiently so that the elderly are guided to form normal structural descriptions of target objects. By contrast, in the Cerella et al. (1991) study, the task was rather open-ended (subjects had to classify an object as one of two types under conditions in which no explicit classification rules were provided, and they had to uncover the rules themselves); elderly subjects may have had difficulties detecting relevant aspects of three-dimensional structure on their own. Thus, under the relatively constrained conditions of our experiment, the elderly may have been able to form normal structural descriptions of target objects.

An alternative possibility, consistent with Cerella et al. (1991), is that the structural description system is impaired with aging and that the elderly might exhibit subtle priming deficits under appropriate conditions. For example, we noted earlier that object decision priming in young subjects is little affected by study–test changes in object size and reflection, thereby suggesting that the structural descriptions underlying priming are relatively abstract representations of relations among object parts (Cooper et al., 1992). Perhaps elderly subjects do not form abstract structural representations and hence would not exhibit such size- and reflection-invariant priming. Similarly, we have found that priming on the object decision task persists with little change over a 1-week delay (Schacter & Cooper, 1992). If the structural description system is in some way impaired by aging, the deficit might be expressed by faster decay of priming over time. More generally, however, we must remain cautious about the conclusion that priming of novel objects is entirely normal in the elderly until further data are available from a range of experimental conditions.

Several points should also be noted about the age-related deficit in explicit memory for novel objects that was observed in both experiments. Deficits in recognition of nonverbal materials in the elderly have been reported previously, but most of these studies have involved pictures of familiar objects or everyday scenes, and the deficits are sometimes observed only under rather circumscribed conditions (e.g., Huppert & Kopelman, 1989; Park, Royal, Dudley, & Morrell, 1988; Pezdek, 1987; Till, Bartlett, & Doyle, 1982). However, several studies have reported age-related impairments in recall and recognition of novel nonverbal materials, including abstract geometric designs (Riege & Inman, 1981; Rybarczyk, Hart, & Harkins, 1987) and unfamiliar faces (Bartlett, Strater, & Fulton, 1991).

As Bartlett et al. (1991) pointed out, age differences on yes–no recognition tasks are frequently (though not always) expressed in terms of elevated false-alarm rates by elderly subjects, with little or no age-related differences in hit rates. We observed this pattern for possible objects in Experiment 1, when the recognition test was given first; in fact, old subjects exhibited a slightly higher hit rate than did young subjects. However, the elderly showed lower hit rates and false-alarm rates than did the young for impossible objects in the recognition-first condition and also when the recognition test was given after the object decision test in Experiments 1 and 2. It is not clear why elderly adults exhibited normal hit rates with possible objects in the recognition-first condition but not otherwise; given the small number of subjects per condition in this experiment, interpretive caution is required. As Bartlett et al. noted, both normal and impaired hit rates have been observed in studies that have used yes–no recognition procedures in studies with elderly adults.

Although our experiments were not designed to illuminate the nature of the elderly's recognition deficit, further investigations of the issue could be pursued profitably in connection with studies that investigate the nature of elderly adults' structural descriptions of novel objects, as discussed earlier. It would be of great interest to determine whether recognition memory deficits are related to, or produced by, low resolution structural descriptions, or whether recognition impairments are attributable to processes occurring outside of a fully intact structural description system. Although we currently favor the latter alternative, experiments that explore this issue—however they turn out—should enhance the understanding of how cognitive aging affects both implicit and explicit memory.

References

Bartlett, J. C., Strater, L., & Fulton, A. (1991). False recency and false fame of faces in young adulthood and old age. *Memory & Cognition, 19,* 177–188.

Cerella, J. (1985). Information processing rates in the elderly. *Psychological Bulletin, 98,* 67–83.

Cerella, J., Milberg, W. P., & Plude, D. J. (1991). *Two and three dimensional pattern perception in elderly adults.* Manuscript submitted for publication.

Chiarello, C., & Hoyer, W. J. (1988). Adult age differences in implicit and explicit memory: Time course and encoding effects. *Psychology and Aging, 3,* 358–366.

Cooper, L. A., Schacter, D. L., Ballesteros, S., & Moore, C. (1992). Priming and recognition of transformed three-dimensional objects: Effects of size and reflection. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 43–57.

Cooper, L. A., Schacter, D. L., & Moore, C. (1991, November). *Orientation affects both structural and episodic representations of 3-d objects.* Paper presented at the Annual Meeting of the Psychonomic Society, San Francisco.

Davis, H. P., Cohen, A., Gandy, M., Colombo, P., VanDusseldorp, G., Simolke, N., & Romano, J. (1990). Lexical priming deficits as a function of age. *Behavioral Neuroscience, 104,* 288–297.

Goodglass, H., & Kaplan, E. (1983). *Assessment of aphasia and related disorders.* Philadelphia: Lea & Febiger.

Goodman, L. A., & Kruskal, W. H. (1954). Measures of association for cross classification. *Journal of the American Statistical Association, 49,* 732–764.

Graf, P. (1990). Life span changes in implicit and explicit memory. *Bulletin of the Psychonomic Society, 28,* 353–358.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic patients. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 501–518.

Hale, W. D., Cochran, C. D., & Hedgepeth, B. E. (1984). Norms for the elderly on the Brief Symptom Inventory. *Journal of Consulting and Clinical Psychology, 52,* 321–322.

Hayman, C. A. G., & Tulving, E. (1989). Contingent dissociation between recognition and fragment completion: The method of triangulation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 228–240.

Hintzman, D. L., & Hartry, A. L. (1990). Item effects in recognition and fragment completion: Contingency relations vary for different subsets of words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 955–969.

Hochberg, J. (1968). In the mind's eye. In R. N. Haber (Ed.), *Contemporary theory and research in visual perception* (pp. 308–331). New York: Holt, Rinehart & Winston.

Howard, D. V. (1991). Implicit memory: An expanding picture of cognitive aging. In K. W. Schaie (Ed.), *Annual review of gerontology and geriatrics* (pp. 1–22). New York: Springer.

Howard, D. V., Fry, A. F., & Brune, C. M. (1991). Aging and memory for new associations: Direct versus indirect measures. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 779–792.

Howard, D. V., & Howard, J. H. (1992). Adult age differences in the rate of learning serial patterns: Evidence from direct and indirect tests. *Psychology and Aging, 7,* 232–241.

Hultsch, D. F., Masson, M. E. J., & Small, B. J. (1991). Adult age differences in direct and indirect tests of memory. *Journal of Gerontology: Psychological Science, 46,* 22–30.

Huppert, F. A., & Kopelman, M. D. (1989). Rates of forgetting in normal ageing: A comparison with dementia. *Neuropsychologia, 27,* 849–860.

Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology, 42,* 333–376.

Light, L. L., & Singh, A. (1987). Implicit and explicit memory in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 531–541.

Light, L. L., Singh, A., & Capps, J. L. (1986). Dissociation of memory and awareness in young and older adults. *Journal of Clinical Experimental Neuropsychology, 8,* 62–74.

McDowd, J. M., & Craik, F. I. M. (1988). Effects of aging and task difficulty on divided attention performance. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 267–280.

Mitchell, D. B., Brown, A. S., & Murphy, D. R. (1990). Dissociations between procedural and episodic memory: Effects of time and aging. *Psychology and Aging, 5,* 264–276.

Moscovitch, M., Winocur, G., & McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzheimer's disease and other neurological disorders. *Journal of Experimental Psychology: General, 115,* 331–347.

Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology, 19,* 1–32.

Park, D. C., Royal, D., Dudley, W., & Morrell, R. (1988). Forgetting of pictures in young and older adults. *Psychology and Aging, 3,* 94–95.

Pezdek, K. (1987). Memory for pictures: A life-span study of the role of visual detail. *Child Development, 58,* 807–815.

Plaut, D. C., & Farah, M. J. (1990). Visual object representation: Interpreting neurophysiological data within a computational framework. *Journal of Cognitive Neuroscience, 2,* 320–343.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology, 36,* 475–543.

Riddoch, M. J., & Humphreys, G. W. (1987). Visual object processing in optic aphasia: A case of semantic access agnosia. *Cognitive Neuropsychology, 4,* 131–186.

Riege, W. H., & Inman, V. (1981). Age differences in nonverbal memory tasks. *Journal of Gerontology, 36,* 51–58.

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

Russo, R., & Parkin, A. J. (1991). *The influence of divided attention and ageing on implicit and explicit memory.* Manuscript submitted for publication.

Rybarczyk, B. D., Hart, R. P., & Harkins, S. W. (1987). Age and forgetting rate with pictorial stimuli. *Psychology and Aging, 2,* 404–406.

Salthouse, T. (1985). *A theory of cognitive aging.* Amsterdam: North-Holland.

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

Schacter, D. L. (1990). Perceptual representation systems and implicit memory: Toward a resolution of the multiple memory systems debate. In A. Diamond (Ed.), Development and neural bases of higher cognition. *Annals of the New York Academy of Sciences, 608,* 543–571.

Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. *American Psychologist, 47,* 559–569.

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. 47–69). Hillsdale, NJ: Erlbaum.

Schacter, D. L. & Cooper, L. A. (1992). [Long-lasting priming of novel objects]. Unpublished raw data.

Schacter, D. L., Cooper, L. A., & Delaney, S. M. (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. *Journal of Experimental Psychology: General, 119,* 5–24.

Schacter, D. L., Cooper, L. A., Delaney, S. M., Peterson, M. A., & Tharan, M. (1991). Implicit memory for possible and impossible objects: Constraints on the construction of structural descriptions. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 3–19.

Schacter, D. L., Cooper, L. A., Tharan, M., & Rubens, A. B. (1991). Preserved priming of novel objects in patients with memory disorders. *Journal of Cognitive Neuroscience, 3,* 118–131.

Schacter, D. L., Delaney, S. M., & Merikle, E. P. (1990). Priming of nonverbal information and the nature of implicit memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 26, pp. 83–123). San Diego, CA: Academic Press.

Schacter, D. L., & Graf, P. (1986). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 432–444.

Schacter, D. L., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1991). The relation between source memory and aging. *Psychology and Aging, 6,* 559–568.

Schacter, D. L., Kihlstrom, J. F., Kaszniak, A. K., & Valdiserri, M. (in press). Preserved and impaired memory functions in elderly adults. In J. Cerella, W. Hoyer, J. Rybash, & M. Commons (Eds.), *Adult information processing: Limits on loss.* San Diego, CA: Academic Press.

Scogin, F. (1987). The concurrent validity of the Geriatric Depression Scale with depressed older adults. *Clinical Gerontologist, 7,* 23–30.

Shimamura, A. P. (1985). Problems with the finding of stochastic independence as evidence for the independence of cognitive processes. *Bulletin of the Psychonomic Society, 23,* 506–508.

Shimamura, A. P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology, 38A,* 619–644.

Squire, L. R. (1987). *Memory and brain.* New York: Oxford University Press.

Till, R. E., Bartlett, J. C., & Doyle, A. (1982). Age differences in picture memory with resemblance and discrimination tasks. *Experimental Aging Research, 8,* 179–184.

Tulving, E. (1983). *Elements of episodic memory.* Oxford: Clarendon Press.

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

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

Warrington, E. K. (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology, 27,* 635–657.

Warrington, E. K. (1982). Neuropsychological studies of object recognition. *Philosophical Transactions of the Royal Society of London, Series B, 298,* 15–33.

Warrington, E. K., & Taylor, A. M. (1978). Two categorical stages of object recognition. *Perception, 7,* 695–705.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1983). Development and validation of a geriatric depression scale: A preliminary report. *Journal of Psychiatric Research, 17,* 37–49.

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