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How Many Memory Systems? Evidence From Aging

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The present research tested Tulving's (1985) ternary memory theory. Young (ages 19–32) and older (ages 63–80) adults were given procedural, semantic, and episodic memory tasks. Repetition, lag, and codability were manipulated in a picture-naming task, followed by incidental memory tests. Relative to young adults, older adults exhibited lower levels of recall and recognition, but these episodic measures increased similarly as a function of lag and repetition in both age groups. No age-related deficits emerged in either semantic memory (vocabulary, latency slopes, naming errors, and tip-of-the-tongue responses) or procedural memory (repetition priming magnitude and rate of decline). In addition to the age by memory task dissociations, the manipulation of codability produced slower naming latencies and more naming errors (semantic memory), yet promoted better recall and recognition (episodic memory). Finally, a factor analysis of 11 memory measures revealed three distinct factors, providing additional support for a tripartite memory model.

The distinction between semantic and episodic memory proposed by Tulving in 1972 has generated a plethora of research, giving the dichotomy unassailable heuristic value. The semantic-episodic distinction has also generated considerable debate over its validity. (For summaries, see McKoon, Ratcliff, & Dell, 1986, and Tulving, 1984, with accompanying commentaries.) One source of data conspicuously neglected in these discussions is the ubiquitous finding of memory decrements in relation to normal aging. Thus, in the present research, age differences in memory serve as one vehicle for investigating the question of how many memory systems there are.

Tulving's (1985) more recent classification calls for three memory systems. If measures tapping different types of memory reveal *similar* patterns of loss in elderly adults, then the theory of multiple memory systems would be neither supported nor disproved. On the other hand, if three classes of memory tasks can be shown to be affected *differently* by aging, then there is evidence to support Tulving's theory of separate memory systems. Thus, three types of memory tasks are investigated in the present research using healthy young and older adults as subjects.

A common strategy for uncovering dissociations between various types of memory is to manipulate an independent variable and then to compare the effects of the variable on two different tasks (cf. Tulving, 1983). Roediger (1984) pointed out that most investigations in search of such functional dissociations typically use only one measure for each type of memory being assessed. The problem with this approach is basically one of convergent validity, because any single measure by itself is logically insufficient to validate a concept. Roediger (1984) suggested that at least two measures of each type of memory are necessary, as this would "ensure that an independent variable has different effects on tasks supposed to engage different systems, but similar effects within the same system" (p. 253). This issue is addressed in the current investigation by taking multiple measures for each of three types of memory. Although chronological age is not a variable that can be manipulated, age differences can be employed as an independent variable in the search for functional dissociations. When the logic of functional dissociation is applied to the concept of multiple memory systems, more age differences should occur between the three types of memory measures than within measures.

The three memory systems in Tulving's (1985) classification scheme are *episodic*, *semantic*, and *procedural*. Episodic memory is the type most often studied in the laboratory, involving conscious recollection for "personally experienced events and their temporal relations" (Tulving, 1985, p. 387). Four measures of episodic memory were employed in the current investigation: free recall, yes–no recognition, changes in recall performance as a function of time, and intrusions during recall. These are all standard measures that are assumed to reflect episodic memory (cf. Underwood, Boruch, & Malmi, 1978).

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Semantic memory is also available to consciousness but, unlike episodic memory, is not tied to spatial and temporal autobiographical contexts. Tulving initially described it as a "mental thesaurus, organized knowledge a person possesses about words and other verbal symbols" (1972, p. 386) and later expanded it to include an "organism's knowledge of its world" (1985, p. 388). Semantic memory measures used in the current study included a standardized vocabulary test, picture-naming latencies, and picture-naming errors (commission and tip-of-the-tongue responses). Picture naming was selected as a measure of semantic memory in particular because there is some evidence (Obler & Albert, 1985) of age-associated difficulties with specific name retrieval. Picture naming should be a sensitive measure of any difficulties in retrieval from semantic memory.

Procedural memory allows an organism to make learned, overt responses in the context of particular stimuli and thus is "prescriptive rather than descriptive: It provides a blueprint for future action without containing information about the past" (Tulving, 1985, pp. 387–388). Procedural memory tasks often require a second presentation of a previously experienced stimulus. For example, in a perceptual identification task, subjects more readily identify briefly presented words that were recently experienced, relative to new words (Jacoby & Dallas, 1981). The primary measure of procedural memory used in the current research was repetition priming, defined as faster naming latencies for previously presented pictures (cf. Carroll, Byrne, & Kirsner, 1985; Mitchell & Brown, 1988). Note that naming a previously seen picture, like word identification, requires no conscious recollection of a specific encounter with the stimulus. Procedural memory measures have also been labeled *implicit memory* (Graf & Schacter, 1985) and *memory without awareness* (Jacoby & Witherspoon, 1982).

Although semantic memory is usually called on in order to make a response, procedural memory seems to be distinct from semantic memory in at least two ways (see Tulving's, 1983, discussion, pp. 105–112). First, priming effects do not transfer well across modalities (Jacoby & Dallas, 1981). Second, repetition priming persists over longer intervals relative to associative (i.e., semantic) priming effects (Dannenbring & Briand, 1982). Thus, "priming is a phenomenon of procedural memory," in that it "reflects an improvement in the facility with which cognitive operations are carried out" (Tulving, 1983, p. 109). Tulving (1983) also stressed procedural memory's role in the *how* of processing in contrast to the *contents* of semantic memory. In the current investigation, procedural memory was assessed via repetition priming in terms of reduced picture-naming latencies, both as a function of simple repetition and the lag between repeated items.

An important additional feature of Tulving's (1985) theory is the *monohierarchical* arrangement of the three systems. Procedural memory is the foundation of the structure, supporting semantic memory as its "single specialized subsystem," which in turn supports episodic memory as its "single specialized subsystem" (Tulving, 1985, p. 387). This monohierarchy has important implications for memory and aging: Episodic memory could malfunction without either of the other two lower systems being affected. On the other hand, if semantic memory is affected adversely by aging, then by definition episodic memory will also be affected. Likewise, if procedural memory is not working properly, then neither semantic nor episodic memory can function adequately. It is worth noting that if the latter were true, then age-related memory data would not help to distinguish between unitary and multiple memory models, as both would predict global impairment.

There are two primary ways to hunt for dissociations in memory phenomena. One is to conduct experiments in which a variable is manipulated. The other is to employ two or more groups of individuals known to differ in memory abilities (e.g., amnesics vs. normals, older vs. younger adults). In the following sections, the research on these two approaches is reviewed.

Experimentally Produced Dissociations

A substantial number of published experiments report dissociations between semantic and episodic memory (for reviews, see McKoon et al., 1986; Tulving, 1984), as well as between episodic and procedural memory (for reviews, see Roediger & Blaxton, 1987; Roediger & Weldon, 1987; Schacter, 1987). Concerning the procedural–episodic distinction, the prototypical finding is that an established manipulation known to affect episodic memory has no effect on procedural memory. For example, Mitchell and Brown (1988) found that episodic recognition memory for pictures declined monotonically over a 1–6 week period, whereas procedural memory for the same stimuli (repetition priming) showed no decrement at all. On occasion, the effects of the same independent variable are even reversed, producing a double dissociation. For instance, Jacoby (1983) found that even though generating a word improved episodic recognition relative to simply reading a word, the exact opposite was true for a procedural (perceptual identification) task: Previously generated words were more poorly identified than were read words. The current study manipulated variables (lag and codability, discussed subsequently) designed to produce functional dissociations between different types of memory.

Dissociations Related to Age and Individual Differences

Much of the support for separate memory systems comes from research on brain-damaged individuals. For example, amnesics that have little or no conscious recollection (episodic memory) for a prior experience reveal normal levels of performance on procedural memory tasks (e.g., Cohen & Squire, 1980; Graf & Schacter, 1985; Jacoby & Witherspoon, 1982; Warrington & Weiskrantz, 1982) or on semantic memory tasks (e.g., Cermak, 1984; Weingartner, Grafman, Boutelle, Kaye, & Martin, 1983; Wood, Ebert, & Kinsbourne, 1982). The amnesic literature will not be discussed further, but a similar research strategy can also be applied to individuals differing in chronological age.

The commonly held notion that memory declines in old age is supported by a variety of evidence. Although there is some debate as to whether normative age differences represent *qualitative* changes in mnemonic processes and/or structures, there is no doubt that the typical *quantitative* difference is real (cf. Arenberg, 1983). Rather than a global decline, however, age-related effects appear to be limited to episodic memory.

Experimental studies on aging and memory typically use two groups of subjects: young adults aged 18–30 years and older adults aged 60–80 years. The vast majority of aging and memory studies have investigated episodic memory in isolation, and a fair number of more recent studies have examined semantic memory. Fewer studies have directly compared episodic and semantic memory performance within the same subjects, and far fewer have investigated procedural memory.

Episodic Versus Semantic Memory in Isolation

Researchers using a wide variety of materials—words, sentences, stories, visual patterns, pictures, and faces—have reported poorer episodic memory performance in older adults, ranging from 50% to 90% of the levels found in younger adults (see reviews by Burke & Light, 1981; Craik, 1977; Perlmutter & Mitchell, 1982; Poon, 1985; Smith, 1980). These findings are not restricted to the laboratory, as older adults also experience more episodic memory failures in their everyday activities relative to young adults (Cavanaugh, Grady, & Perlmutter, 1983).

A number of studies have focused solely on semantic memory performance in relation to aging. With few exceptions, the evidence suggests that retrieval from semantic memory either remains stable with increased age or even improves. On memory tests for factual information (e.g., historical events, geography, famous personalities), older adults perform just as well as younger adults and sometimes better (Botwinick & Storandt, 1980; J. L. Lachman & Lachman, 1980; Perlmutter, 1978; Perlmutter, Metzger, Miller, & Nezworski, 1980). A similar absence of age differences occurs in vocabulary tests and word retrieval tasks, such as generating associates or category exemplars (Botwinick, 1977; Burke & Peters, 1986; Drachman & Leavitt, 1972; Eysenck, 1975; Howard, 1980; Perlmutter & Mitchell, 1982). Retrieval latency patterns (i.e., as a function of frequency, familiarity, or category typicality) suggest equivalent levels of semantic activation in young and older adults, as measured by lexical decision tasks (Bowles & Poon, 1985; Chiarello, Church, & Hoyer, 1985), reading words (Cerella & Fozard, 1984; Waugh & Barr, 1980; Waugh, Thomas, & Fozard, 1978), naming pictures (Poon & Fozard, 1978; Thomas, Fozard, & Waugh. 1977), naming colors (Howard, Lasaga, & McAndrews, 1980), and category or synonym judgments (Madden, 1985; Mueller, Kausler, & Faherty, 1980; Petros, Zehr, & Chabot, 1983). Occasionally, age differences are reported in the kinds and commonality of free associates (Perlmutter, 1979; Riegel & Riegel, 1964), in the degree of name agreement for pictures (Butterfield & Butterfield, 1977), and in word retrieval inhibition (Bowles & Poon, 1985). The vast majority of studies, however, reveal little or no age difference in the amount, type, and way in which information is retrieved from semantic memory.

Semantic and Episodic Memory in the Same Individuals

In a number of more recent studies, semantic and episodic memory performance have been examined within subjects. A within-subjects approach has several advantages. First, a stronger case can be made for the general phenomenon of episodic decline versus semantic stability seen across different studies and subjects if it can be replicated within the same individuals. Second, a materials confound can be eliminated as an alternative explanation when the same stimuli are used to measure semantic activation and episodic retrieval. Third, the relationship between the two types of memory can be examined directly.

A typical procedure is to present a semantic memory task first and then to test episodic memory for the materials used in the first task. For instance, Mitchell and Perlmutter (1986) first had subjects make speeded category membership judgments about target words surrounded by flanker words. Subsequently, subjects were given recall and recognition tests for the original targets and flankers. The episodic recall and recognition tasks revealed the usual age-related decrement. In contrast, both young and old subject's reaction time patterns revealed a flanker effect (i.e., same-category flankers produced faster target judgment times relative to different-category flankers), suggesting similar semantic activation in the two groups.

This age by memory type dissociation has been reported in a number of recent studies: Age-related deficits are found for episodic memory measures but not for semantic memory measures. Semantic activation is most often assessed through lexical decision facilitation for identifying target words preceded by semantically related prime words (cf. Meyer & Schvaneveldt, 1971). The magnitude of facilitation is equivalent in young and old adults when the prime is a related word (Howard, 1983; Howard, McAndrews, & Lasaga, 1981; Howard, Shaw, & Heisey, 1986), a category superordinate (Burke, White & Diaz, 1987), or a semantically related sentence (Burke & Yee, 1984; Cohen & Faulkner, 1983; Madden, 1986). In spite of the older adults' apparent equivalence in semantic retrieval efficiency, their level of episodic memory performance for the targets and primes is significantly below that of the younger group. Similarly, older adults with higher knowledge scores perform more poorly than young adults on episodic tests for the source and context of that knowledge (McIntyre & Craik, 1987).

Procedural and Episodic Memory in the Same Individuals

Procedural memory in aging has been investigated in a number of recent studies. In all of these, episodic retention has also been tested, providing a valuable comparison of age differences in these two types of memory. In these studies, eight different procedural memory tasks were tested: word fragment completion, word stem completion, mirror-inverted text reading, perceptual identification, lexical decision, picture naming, associative priming, and homophone spelling. These tasks also fall under the atheoretical rubric of *repetition priming*; that is, performance is facilitated by a single prior exposure. In the studies summarized in Table 1, 13 of 14 report age-related deficits in episodic measures, whereas only 2 report a reliable age difference in procedural memory tasks. Thus, there is strong evidence from aging supporting a distinction between procedural and episodic memory.

The Current Investigation

In addition to using individuals differing greatly in age, the present research also manipulated two independent variables within subjects in a further attempt to uncover memory dissociations. The two manipulated variables were codability of the pictorial stimuli and lag interval between repeated presentations of pictures.

Codability is known to affect speed of retrieval from semantic memory: High-codability pictures are named more rapidly than pictures with lower codability (e.g., R. Lachman & Lachman, 1980). Operationally, codability is defined by the proportion of subjects that give the same name for a particular picture. In the Snodgrass and Vanderwart (1980) norms, for example, all subjects named a drawing of a chair the same name (*chair*), whereas a picture of a dresser elicited many names (*dresser, bureau, chest of drawers,* etc.). The picture of a chair is considered highly codable, whereas the dresser is less codable. Although frequency of occurrence and age of acquisition (of a picture's name) are good predictors of naming latency (Carroll & White, 1973; Oldfield & Wingfield, 1965), a picture's normative codability seems to be the best overall predictor (Gilhooly & Gilhooly, 1979; R. Lachman, 1973; R. Lachman & Lachman, 1980; R. Lachman, Shaffer, & Hennrikus, 1974).

The effects of codability on episodic memory have not been investigated previously. If codability effects are similar to the frequency effect with words (the measurers were correlated in the present stimuli), episodic recognition should be higher for low- relative to high-codability pictures (but free recall may show the opposite pattern; cf. Mandler, Goodman, & Wilkes-Gibbs, 1982). In contrast, high-codability pictures should be named faster than low-codability pictures, implying easier access from semantic memory. Such an outcome would represent a functional dissociation.

Lag effects—or the number of items intervening between repeated target items—have long been studied in episodic tasks. Generally, episodic memory performance improves monotonically as a function of increased lag. This phenomenon holds for words (Glenberg, 1977; Madigan, 1969; Melton, 1970), sentences (Rothkopf & Coke, 1966), passages (Kraft & Jenkins, 1981), and pictures (Hintzman & Rogers, 1973). (For exceptions, see Toppino & Gracen, 1985.) In contrast, the magnitude of repetition priming has often been shown to decrease across similar lag intervals (Durso & Johnson, 1979;

Table 1
Age Differences in Procedural Versus Episodic Memory Tasks

	Episodic-memory task			Procedural-memory task		
Study	Young		Older	Young		Older
		Recognition			Homophone spelling	
Howard, 1986	74%	★	60%	11%		9%
Rose, Yesavage, Hill, & Bower, 1986	88%		84%	12%	★	−4%
Howard, Heisey, & Shaw, 1986		Cued recall			Associative priming	
Experiment 1	69%	★	37%	88 ms		101 ms
Experiment 2	49%	★	32%	104 ms	★	32 ms
Rabinowitz, 1986	70%	★	35%	178 ms		162 ms[a]
Light, Singh, & Capps, 1986		Recognition			Word-fragment completion	
	52%	★	41%	52%		48%
Light & Singh, 1987		Free recall			Word-stem completion	
Experiment 1	20%	★	10%	27%		21%
		Cued recall			Word-stem completion	
Experiment 2	55%	★	27%	28%		20%
		Free recall			Perceptual identification	
Experiment 3	22%	★	15%	14%		11%
		Cued recall			Picture naming	
Mitchell & Schmitt, 1988	78%	★	60%	125 ms		158 ms
		Recognition			Lexical decision	
Moscovitch, 1982		better worse		63 ms		53 ms[b]
Moscovitch, Winocur, & McLachlan, 1986		Recognition			Reading time	
Experiment 1	90%	?	62%	4.7 s		6.8 s
Experiment 2	35%	★	22%[c]	160 ms	?	500 ms[d]
Experiment 3	91%	?	68%[e]	200 ms	?	450 ms[f]

Note. ★ = reliable difference; ? = inferential statistics not reported. No mark indicates the difference was not statistically significant.
[a] From his Figure 2. [b] From his Figure 8. [c] From their Figure 1. [d] From their Figure 3. [e] From their Figure 5. [f] From their Figure 6.

Kirsner & Smith, 1974). Thus, lag should produce a double dissociation between procedural and episodic memory: With longer lags, episodic performance should increase, whereas procedural performance should decrease.

The vast majority of published studies reporting dissociations are limited to episodic versus semantic, or episodic versus procedural comparisons. Semantic and procedural memory have been contrasted only rarely, but at least one dissociation has been reported here as well (Dannenbring & Briand, 1982). Conspicuously absent are studies that compare all three types—episodic, semantic, and procedural—within one experiment. This three-way comparison constituted a central goal of the current research.

An adequate assessment of a tripartite theory requires that three representative types of memory tasks be examined in one study. A major advantage of the present design is that the data can be factor analyzed for memory structure. Thus, a final goal of the current investigation was to subject all measures to a factor analysis. If the right tasks are used, and if there are at least three memory systems, the presence of at least three separate factors should be revealed.

Method

Subjects

A total of 96 adults served as subjects. The 48 young adults were graduate and undergraduate students at the University of Minnesota, most of whom received course credit for participating. Their ages ranged from 19 to 32 years ($M = 22.3$, $SD = 3.0$); years of formal education ranged from 13 to 22 ($M = 14.4$, $SD = 1.8$). The 48 older adults were either University of Minnesota alumni or their spouses who agreed to participate without compensation after being contacted by letter and by phone. All were community dwellers and drove or walked to the laboratory on their own. Their ages ranged from 63 to 80 years ($M = 70.3$, $SD = 4.2$), and years of formal education ranged from 14 to 20 ($M = 16.2$, $SD = 0.9$). Most of the subjects worked at least part time. The subjects' characteristics are summarized in Table 2.

The older adult sample had significantly more years of formal education relative to the young adults, $F(1, 94) = 36.77$, $MS_e = 2.05$, $p < .01$, and also rated their emotional well-being higher, $F(1, 94) = 18.91$, $MS_e = 1.02$, $p < .01$. The physical health ratings did not differ reliably, $F < 1$.

Table 2
Subject Sample Characteristics

	Young adults			Older adults		
Variable	*M*	*SD*	Range	*M*	*SD*	Range
Chronological age	22.3	3.0	19–32	70.3	4.2	63–80
Years of education	14.4	1.8	13–22	16.2	0.9	14–20
Health rating[a]	5.6	0.9	4–7	5.4	1.4	1–7
Emotional rating[a]	5.2	1.1	3–7	6.1	0.9	3–7
Vocabulary[b]	51.0	9.7	33–70	60.3	4.9	44–69
Block design[c]	39.6	8.7	18–51	30.6	8.1	16–49

[a] Scale values: 1 = poor; 4 = average; 7 = excellent. [b] WAIS—R Vocabulary subtest maximum possible = 70. [c] WAIS—R Block Design subtest maximum possible = 51.

The psychometric scores replicate the "classic aging pattern" (Botwinick, 1977). To wit, younger adults scored higher on the Wechsler Adult Intelligence Scale—Revised, (WAIS—R) Block Design subtest, $F(1, 94) = 27.34$, $MS_e = 70.78$, $p < .01$, whereas older adults had superior performance on the WAIS—R Vocabulary subtest, $F(1, 94) = 34.58$, $MS_e = 59.39$, $p < .01$. The scale scores were all above the standardized norms, indicating that both age groups were above average.

Materials

Apparatus. A Kodak slide projector presented stimuli on a rear-view screen that measured 28 cm wide by 20.5 cm high. The screen was located approximately 160 cm from the subject, who sat at the end of a long table across from the screen. The center of the screen was about 24 cm above the table level, roughly at eye level. A photocell in the projector initiated a timer when a slide was presented. When the subject spoke, a Grason-Stadler voice-operated relay stopped the timer and advanced the projector to a blank slide. All timing, recording, and running of the equipment were done by an Apple II microcomputer.

Stimuli. The primary stimuli for naming were 96 pictures selected from a pool of 260 line drawings normed on young adults (Snodgrass & Vanderwart, 1980). There were 48 items each for high and low codability, defined according to H values. When all subjects in a sample agree on a single name (100% name agreement), that item has an H value of 0. As name agreement decreases, the H index rises according to a log function. For the normed pool, H ranges from 0 to 2.55 with a median of 0.42. High-codability items ranged from 0 to 0.28 ($M = 0.06$, $SD = 0.08$), and low-codability items ranged from 0.56 to 2.55 ($M = 1.19$, $SD = .44$). The high-codability items also were higher in Kucera-Francis frequency (range 0–352; $M = 41.4$, $SD = 70.9$) than the low-codability items (range 0–118; $M = 14.5$, $SD = 22.1$).

Ninety-six additional pictures were drawn either from the pool or by an artist to serve as foils in the recognition task. Most foils were selected from the same taxonomic category as the original items (e.g., *door-window, mitten-glove*) and often shared perceptual features as well (e.g., *chisel-screwdriver, pencil-pen*). Another 30 items with a medium range of codability ($M = 0.43$) were used for warm-up trials.

Lag was defined by the number of items intervening between the first and second occurrences of the target pictures. Target items were assigned to a 2 (high and low codability) by 4 (one occurrence, and 5-, 25-, and 50-item lags) matrix, so that an equal number of pictures (12) was contained in each cell. Each of 72 pictures appeared twice and each of the remaining 24 pictures appeared only once. Latencies to name the latter group of items served as a baseline against which to evaluate the degree of facilitation due to repetition and lag. These baseline items occurred roughly at the same trial positions as the first and second occurrences of the other items. Four lists were constructed such that all items occurred equally often in each of the four lag cells. Roughly one quarter of the subjects was assigned to each list.

Procedure

All subjects first signed a participation consent form and then filled out a questionnaire that requested information such as chronological age and years of formal education. Subjects also rated their physical and emotional well-being on 7-point scales. The remainder of the tasks were administered in the following order: picture naming, WAIS—R Block Design subtest, WAIS—R Vocabulary subtest, free recall, and recognition. The order was the same for all subjects, who were given breaks after each task. Subjects were tested individually in sessions lasting from 1 to 1½ hr. At the end of a session, subjects were debriefed on the nature and goals of the study.

For the picture-naming task, subjects were seated in front of a rear projection screen and told to name each picture as quickly as possible, but not at the expense of making errors. They were told that some pictures had more than one acceptable name, but to "give the most appropriate name that comes to mind" for such items. When ready, subjects initiated each trial by pressing a button. On pressing the button, the following sequence ensued: (a) a 750-ms interval elapsed; (b) a picture appeared on the screen; (c) when the subject spoke (i.e., uttered a good response, a wrong response, or said "uh" or "I don't know"), the picture disappeared and the projector advanced to a blank; (d) the experimenter typed the name given by the subject and a scoring code into the computer; and (e) the computer emitted a tone indicating that the equipment was ready for another trial, which the subject again initiated by pressing a button. Subjects were told that they could take as much time as they pleased during the intertrial intervals.

Naming errors, which included omission errors (tip-of-the-tongue [TOT], don't know name, and don't know object responses) and commission errors (a name not given by at least 2 subjects in the norms), were recorded as well as trials on which the voice key malfunctioned. When subjects were unable to name a picture, they were asked if they knew the object's name or were familiar with it. If the answer was negative, the response was coded as DKN (don't known name) or DKO (don't know object). If the answer was affirmative, they were asked to identify the item's name from four alternatives. When the correct name was identified, the item was considered a positive TOT (after the procedure used by Brown & McNeill, 1966).

Subjects received 30 practice trials followed by 168 experimental trials. Subjects were told that some pictures would appear more than once, but no mention was made of the subsequent retention tests. The practice trials were used to calibrate the voice key to a particular subject's level and to familiarize subjects with the procedure. The carousel trays on the slide projectors had to be changed twice during the session (after Trials 68 and 134, out of 198 total), which required approximately 20–30 s. The picture-naming task took about 15–20 min. Following the naming task, subjects were administered the Block Design and Vocabulary subtests of the WAIS—R, requiring 15–20 min.

The incidental recall and recognition tasks were last (in that order), thus allowing ample time for the dissipation of any recency effects. For free recall, subjects were handed a blank sheet of lined paper and asked to write down the names of all the pictures they could remember. They were given 5 min for this task, during which each 1-min period of recall was marked. The recognition task involved the use of the rear projection screen again: 192 pictures were presented (96 targets and 96 foils). A two-choice button box was placed in front of the subjects, who were told to decide whether each picture was one they had named earlier and to press the corresponding *yes* or *no* button. Each picture was presented one at a time and stayed on until the subject pressed a button, at which time the next picture was presented. One randomized order was constructed with the restriction that no more than 4 targets or foils occurred in a row. The recognition task required 5–10 min.

Design

The major manipulations were within subjects: codability of the picture (high vs. low), repetition (one vs. two presentations), and lag interval (5, 25, or 50 items) between the first and second presentations. The only between-subjects manipulation was list assignment, which was counterbalanced across subjects. Age was of course the major between-subjects variable. The primary dependent variables were naming latencies, naming errors, number of items recalled, and number of items recognized.

Results

The data are presented in four sections: (a) procedural memory, (b) semantic memory, (c) episodic memory, and (d) factor analysis. The primary data in the first three sections were analyzed by univariate mixed-factorial analyses of variance (ANOVAS). Age group and gender[1] were between-subjects factors, and codability and lag or repetition were within-subjects factors. Given the large number of analyses conducted, a conservative .01 alpha level was used to determine statistical significance, unless noted otherwise. The Geisser–Greenhouse adjustment was used for repeated measures.

Procedural Memory

Two indices were hypothesized to tap procedural memory: (a) naming latencies as a function of repetition (i.e., the difference between repeated vs. nonrepeated items), and (b) naming latencies as a function of lag (i.e., the magnitude of repetition priming across different spacings). Median latencies were calculated for each cell in the lag by codability matrix for each subject separately, using only error-free trials. Trials were thrown out because subjects made naming errors (2.4%), because the equipment malfunctioned (3.3%), or because a particular item's other occurrence was one of the first two types of error (3.6%). Because means and variances were correlated, and because the latency data were positively skewed, identical sets of ANOVAS were conducted on the medians and on log transformations of the medians (cf. Kirk, 1968). Both analyses resulted in the same significant effects, so only the medians analyses are reported.

Mean naming latencies as a function of repetition (first vs. second occurrence), codability, lag, and age are presented in Table 3. For the purpose of evaluating procedural memory, the effects of repetition and lag are of primary interest. Repetition priming was very robust, as revealed by substantially faster naming latencies for the second occurrence ($M = 767$) compared with the first ($M = 923$), $F(1, 92) = 533.12$, $MS_e = 13208$. The interaction between repetition and codability was reliable, $F(1, 92) = 208.75$, $MS_e = 6229$. Repetition effects were reliable for both levels of codability (discussed later), but low-codability items showed a greater magnitude of repetition priming relative to high-codability items.

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[1] Gender was included as a factor in the analyses but is not mentioned further, as neither the theoretical nor empirical bases are sufficient to make predictions on the basis of sex. For the interested reader, the gender effects paralleled the age-related main effects: Women in both age groups revealed significantly higher levels of recall and recognition, whereas there were no reliable sex differences in the procedural and semantic memory tasks. Note that two entirely different individual difference variables produced the same patterns of dissociations.

Table 3
Mean Naming Latencies as a Function of Occurrence, Lag, Codability, and Age

Age groups	Single items	Lag (repeated items) 5	25	50
	First occurrence			
Young adults				
High codability	782	784	777	764
Low codability	1,017	1,005	1,020	998
Older adults				
High codability	834	825	838	823
Low codability	1,070	1,072	1,101	1,072
	Second occurrence			
Young adults				
High codability		683	681	694
Low codability		761	767	804
Older adults				
High codability		736	739	744
Low codability		857	849	888

Note. Means are in milliseconds based on medians.

Lag affected repeated item latencies, but not first occurrence latencies, confirmed by a reliable lag by occurrence interaction, $F(2, 184) = 12.48$, $MS_e = 3842$. Lag-50 items were named relatively slower on their second occurrence compared with lag-5 and lag-25 items. Thus, although the effects of repetition were still present after a 50-item lag, the magnitude of the facilitation declined past the 25-item interval.

Base-rate latencies were calculated from the medians of all first occurrences. Older adults had slower mean base-rate latencies (954 ms, $SD = 150$) than younger adults (893 ms, $SD = 109$), although this difference fell short of significance, $t(94) = 2.28$, $p = .025$. The older adults' latencies were 6.8% slower than those of the younger adults. This magnitude is comparable to that found in simple vocal reaction times by Nebes (1978; 5.6%) and Charness (1987; 8.6%), both of whom also reported statistically nonsignificant age differences. This slower naming speed is assumed to reflect nonspecific age differences in processing speed, or "general slowing in speed of behavior" (Birren, Woods, & Williams, 1980, p. 305). The absence of any reliable interactions between age and repetition or lag (all Fs < 1) supports a peripheral—as opposed to a central—interpretation of age-related slowing in processing. In other words, both young and old adults' naming latencies benefited similarly from repetition and lag. This can be seen more clearly in the priming effects, discussed next.

Priming effects, calculated as difference scores or slopes, are seen as purer measures of memory than absolute or base-rate naming latencies, because the latter are contaminated by other age-related differences in speed of processing that may not be related directly to memory processes. This logic is similar to Sternberg's (1969) approach in short-term memory scanning and has been used in other research in which age-related differences are involved (e.g., Manis, Keating, & Morrison, 1980).

To evaluate priming effects, reaction time differences can be examined two ways. One way is to take the difference between the first and second occurrences of the same items. This has the advantage of controlling for individual item effects but it can overestimate repetition and lag effects if practice effects are present, or underestimate the effects if there is fatigue. These potential problems persuaded Durso and Johnson (1979) to insert baseline items (that appeared only once) throughout the trial sequence. The amount of facilitation is calculated by subtracting the median reaction time for a particular lag cell from the median baseline time. The data were initially analyzed using both methods. The magnitude of repetition priming was slightly larger for the baseline – second occurrence method ($M = 159$ ms) than the first – second method ($M = 140$ ms). Because both methods produced similar outcomes in the ANOVAS, Durso and Johnson's precedent was followed and the analyses reported below were conducted on the baseline – second occurrence differences.

Priming effects are presented graphically in Figure 1. First, these data suggest little or no evidence of age differences in repetition priming. With the exception of one older woman, *every subject* revealed positive priming (i.e., faster latencies on the second occurrence). The mean priming effect was slightly larger for the young (168 ms, $SD = 90$) than for the older adults (150 ms, $SD = 111$). Neither the age main effect nor any interactions involving age approached statistical significance, Fs < 1.

Second, priming declined across lag in a similar manner for the majority of subjects in both age groups. Twelve young and 16 older adults, however, had negative lag slopes; that is, the magnitude of priming actually increased over longer intervals rather than declining. The older group's mean priming decline was smaller (39 ms, $SD = 102$) than that of the young group (59 ms, $SD = 95$), but this difference was not reliable, $t(94) = .79$, $p = .43$. Collapsed across age and codability, priming declined from 167 to 166 to 143 ms for 5-, 25-, and 50-item lags, respectively, $F(2, 184) = 13.03$, MS_e 2702. Obviously, the only reliable change occurred between lags 25 and 50, confirmed by a Newman–Keuls test. Furthermore, lag interacted with codability, $F(2, 184) = 4.53$, $MS_e = 2842$ (Geisser-Greenhouse $p = .0125$). Thus, the lag effect was due primarily to the 25- to 50-lag interval in low-codability items: Priming declined from 235 to 197 ms, $t(95) = 3.72$. The decline in priming across the same interval was not reliable for high codability (98 to 89 ms), $t(95) = 1.96$, $p = .053$.

Third, low-codability pictures ($M = 222$) exhibited greater repetition priming than high-codability pictures ($M = 96$), $F(1, 92) = 58.33$, $MS_e = 39802$. No other effects were reliable.

To summarize, neither simple repetition priming nor reduction in priming over short retention intervals revealed reliable age differences. Simple repetition priming slightly favored the young, but they also experienced a slightly greater loss of priming over a 50-item interval. These data suggest that procedural memory may be immune from age-related declines in cognitive functioning.

Semantic Memory

Four measures of semantic memory were available: name-retrieval failures, name-retrieval efficiency, name consistency,

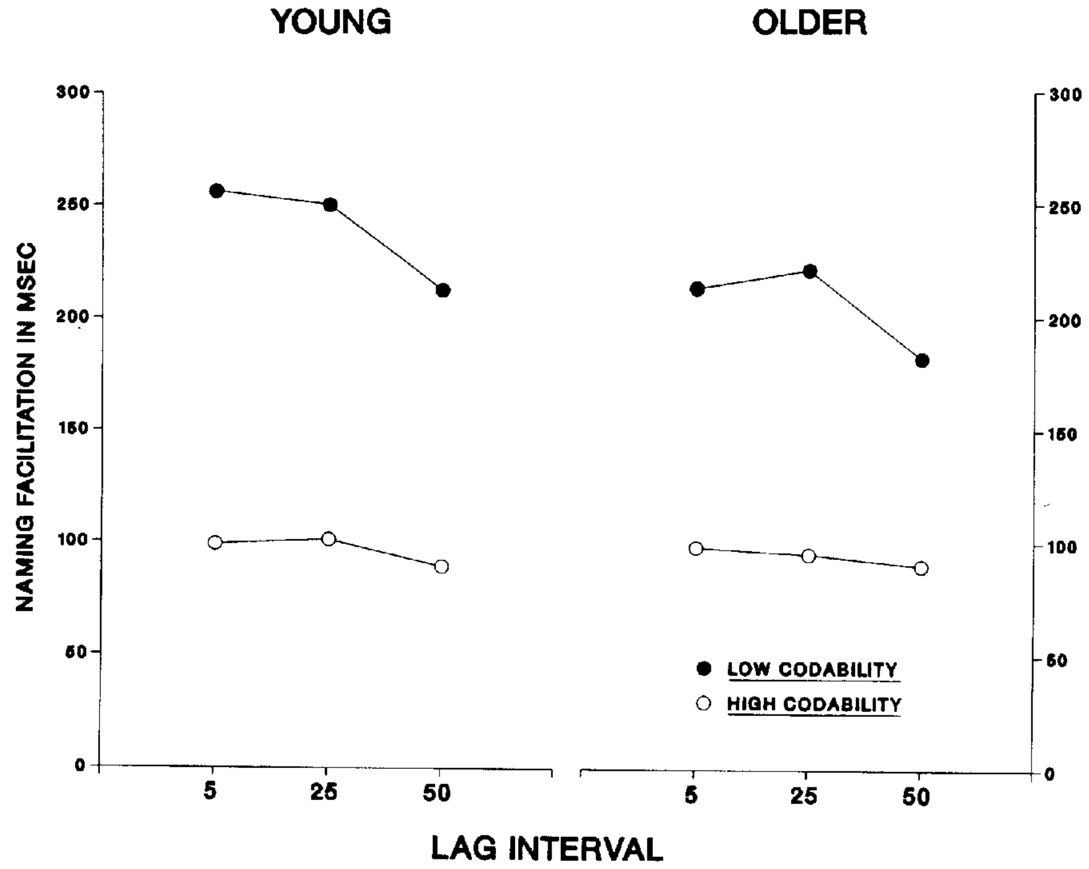

Figure 1. Mean repetition priming (baseline-second occurrence) as a function of lag, age, and codability.

and vocabulary scores. Name-retrieval failures, or errors made during the picture-naming task, were classified into two groups: TOT and commission errors. (The DKOs and DKNs occurred too infrequently to score.) The total numbers of TOTs and naming errors made by all subjects and the mean error rates—based only on the first occurrence trials—are presented in Table 4.

Table 4
Total Naming Errors and Mean Error Rates (%) in Young and Older Adults as a Function of Error Type and Codability

	Young adults		Older adults	
Errors	Total	*M*	Total	*M*
By type				
Tip-of-the-tongue	64	0.8	54	0.6
Commission errors	145	1.8	132	1.6
By codability				
Low codability	183	4.5	163	4.0
High codability	26	0.6	23	0.6
Total	209	2.6	186	2.3

It is clear from the data in Table 4 that there are no meaningful age differences for either type of retrieval error. In fact, the older adults tended to make slightly fewer errors than the young: 2.3% versus 2.6% overall. As expected, most naming errors occurred on low-codability pictures (346 vs. 49 for high). Commission errors consisted primarily of another member within a picture's taxonomic category or the superordinate category name. There were large individual differences in the number of total naming errors, ranging from 0 to 16. Subjects were classified into low (0–1), average (2–6), or high (7–16) naming error rates. Five, 36, and 7 young adults, and 10, 31, and 7 older adults, respectively, fell into these three categories, revealing no reliable difference, χ^2 (2, $N = 96$) = 2.04, $p > .30$.

Semantic retrieval efficiency was defined as the difference in latency between high- and low-codability items. Because the intercept of picture-naming latency includes general age differences in processing speed and other components beside retrieval (e.g., encoding, responding), the slope is considered to be a "purer measure ... [that] more accurately and uniquely represent[s] the retrieval process" (Ford & Keating, 1981, p. 237). Steeper slopes (i.e., larger differences scores) suggest relatively less efficient retrieval from semantic memory, as reported in children's performance on semantic verification tasks (Ford & Keating, 1981). Mean latencies, based on medians of first occurrences only, are presented in Table 5 as a function of codability and age. The mean difference scores were 233 ms for young (SD = 96) and 249 for older adults (SD = 122); the difference was not significant, $t(94) = 0.69$, $p = .49$.

Naming consistency was defined as the extent to which the same name was produced for an item on two occurrences. Semantic retrieval consistency has been examined in the context of word associations, with mixed results. One study (Perlmutter, 1979) reported an age-related decline in response consistency (i.e., a greater number of associates were produced to the same stimulus), but two other studies found no age differences in consistency (Burke & Peters, 1986; Perlmutter & Mitchell, 1982). Naming consistency scores were calculated for each subject by summing the total number of repeated items (possible = 72) for which the same name was given twice. Older adults' consistency scores (M = 90.0%) were not reliably different from the young adults' (M = 91.4%), $F(1, 92) = 1.09$. Naming was significantly more consistent for high-codability items (M = 96.9%) than it was for low-codability items (M = 84.4%), $F(1, 92) = 212.94$, $MS_e = 1.59$, and this pattern was the same for both age groups, $F < 1$.

Knowledge of one's native language is assumed to be a part of semantic memory (cf. Tulving, 1972). So, WAIS—R vocabulary scores were included as a final measure of semantic memory (see Table 2). Older adults scored significantly higher on vocabulary scores compared with younger adults, $F(1, 92) = 35.22$, $MS_e = 58.31$.

To summarize, semantic memory measures consisted of picture-naming errors, TOTs, retrieval efficiency in picture-naming latencies, naming consistency, and WAIS—R Vocabulary scores. Only the latter revealed an age difference, in favor of the older adults. Thus, semantic memory functioning, like procedural memory, shows no evidence of age-related decline. The vocabulary data even imply age-related improvement in this type of memory.

Episodic Memory

The primary measures used to tap episodic memory are old friends, free recall and recognition tests. Both measures were analyzed separately for the effects of repetition and lag. Repetition effects were assessed by comparing one-occurrence items with two-occurrence items (collapsed over lags 5, 25, and 50). Lag effects were assessed by comparing the three lag intervals only for items that had occurred twice.

Table 5
Mean Naming Latencies for First Occurrence of Pictures According to Age and Codability

	Codability	
Age groups	High	Low
Young adults	777	1,010
Older adults	830	1,079

Note. Means are in milliseconds based on medians.

Recall. Overall, young adults recalled significantly more pictures (M = 35.1, SD = 7.2) than did older adults (M = 30.5, SD = 7.0), $F(1, 92) = 13.59$, $MS_e = 2.61$. Intrusions—items recalled that were not actually presented—occurred at a rate too low for parametric analysis. Fifteen of the young adults and 18 of the older adults had 1–4 intrusions, while the remainder had none. A contingency analysis with subjects falling into 0, 1, or 2–4 intrusions revealed that this age difference was not reliable, χ^2 (2, N = 96) = .58. Four young and 10 older adults recalled the same item twice, and this difference was also not statistically significant, χ^2 (1, N = 96) = 3.01.

The repetition effect can be seen in Figure 2. Pictures named twice were recalled at significantly higher levels than those named once, $F(1, 92) = 209.06$, $MS_e = 1.01$. Also, low-codability pictures were recalled at higher levels than high-codability pictures, $F(1, 92) = 19.84$, $MS_e = 1.71$. However, the interaction between codability and repetition was significant, $F(1, 92) = 9.95$, $MS_e = 2.03$. Tukey's test revealed that the repetition effect was reliable for both high and low codability, but that the superior recall of low-codability items was limited to repeated items. As is apparent in Figure 2, none of these effects interacted reliably with age, Fs < 1.

The effects of lag are presented in Figure 3. The main effect was statistically significant, $F(2, 184) = 9.68$, $MS_e = 2.83$, and a Newman-Keuls test revealed that only the difference between lags 5 and 25 was reliable (Lag 5, M = 4.04; Lag 25, M = 4.69; Lag 50, M = 4.70). However, the lag by codability interaction was also reliable, $F(2, 184) = 5.93$, $MS_e = 2.37$. The interaction reflects the fact that the lag manipulation was effective only for low-codability items, with no significant impact on recall of high-codability items. Furthermore, Tukey's test revealed that only the difference between low-codability lags 5 and 25 was reliable. Thus, while the repetition effect was robust, the lag effect was rather fickle. Contrary to appearance, none of the interactions among age, lag, and codability was reliable, Fs < 1.

The final analysis of free recall data was done with 1-min recall periods as an independent variable. In Figure 4, mean items recalled are plotted as a function of time period and age. Clearly, both main effects of time period, $F(4, 368) = 271.17$, $MS_e = 6.73$, and age, $F(1, 92) = 11.64$, $MS_e = 8.74$, were significant. The interaction between age and time period was not reliable, $F(4, 368) = 1.25$.

All three of the foregoing analyses confirm two things about age differences in recall: (a) Age differences are quantitatively measurable and reliable; however, (b) age differences are not qualitative. In other words, even though significant age main effects were present in all instances, both encoding factors (repetition, lag, codability) and retrieval factors (time periods) produced similar patterns in the two age groups.

Recognition. The recognition data were first scored for hits and false alarms. Older adults had lower hit rates (89.8 vs. 91.8), $t(94) = 2.08$, $p < .05$, and significantly higher false alarm rates (7.7 vs. 3.1), $t(94) = 4.32$, than young adults. Corrected recognition scores (hits–false alarms) were thus

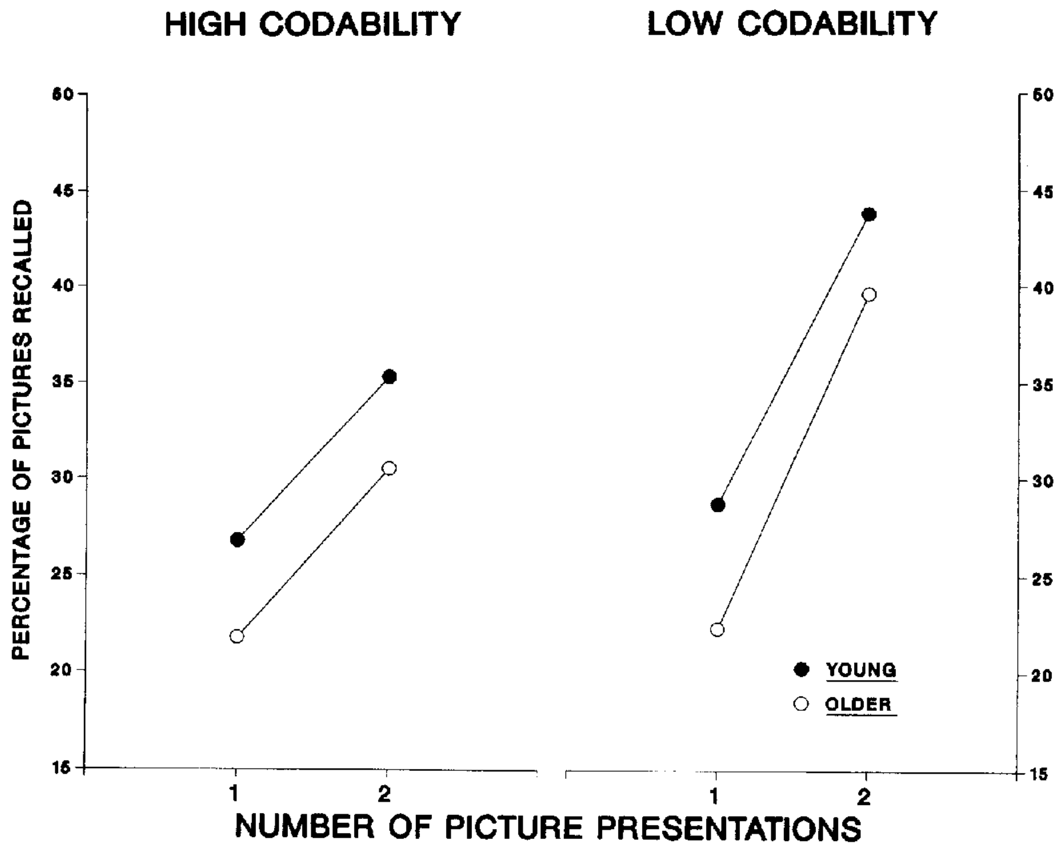

Figure 2. Mean percentage of pictures recalled as a function of repetition, codability, and age group.

significantly higher in the young (M = 88.7, SD = 5.6) than in the older group (M = 82.1, SD = 9.2), $F(1, 92) = 19.02$, $MS_e = 1.52$. Signal detection analyses revealed a similar pattern: The young adults had significantly higher d' scores (M = 3.77, SD = 0.59) compared with older adults (M = 3.24, SD = 0.73), $t(94) = 3.96$. This occurred in spite of the younger adults' somewhat stricter (but nonsignificant) response criterion (β M = 1.58) compared with older adults (β M = 1.34), $t(94) = .74$. Corrected recognition scores were used in the subsequent analyses.

Corrected recognition rates are presented in Figure 5 as a function of repetition, codability, and age group. In spite of ceiling effects, the main effects found in recall (repetition, codability, and age) were all replicated in the recognition data. Repeated pictures were better recognized (M = 10.9) than single-occurrence pictures (M = 9.9), $F(1, 92) = 75.57$, MS_e = 1.30. Low-codability pictures were recognized at higher rates (M = 10.8) than high-codability pictures (M = 10.1), $F(1, 92) = 44.45$, $MS_e = 1.19$. The interactions between age and codability and between repetition and codability were statistically significant but are most likely spurious due to ceiling effects.[2]

In Figure 6, corrected recognition rates are shown as a function of lag, codability, and age. Again, the same main effects found in recall (lag, codability, and age) emerged in spite of ceiling effects. The main effect of lag was reliable, $F(2, 184) = 11.94$, $MS_e = 1.35$, but both the Lag × Codability and Lag × Age × Codability interactions were statistically significant. Although ceiling effects again preclude serious consideration of these interactions, it is interesting to note that the older adults failed to benefit from lag 5 to lag 25 under high codability. The absence of an increase cannot be blamed on ceiling effects, particularly in light of the rise from lag 25 to lag 50, which is the only significant difference (by Tukey's test) among all lag intervals (refer to Figure 6). This is precisely the opposite of the locus of the lag effect in recall, which occurred from lag 5 to lag 25, but not from lag 25 to lag 50, and only in low codability (refer to Figure 3). Furthermore, the benefit of lag in recall was experienced by both age groups. Thus, the failure of older adults to benefit from lag in this case represents the only instance in this study where there is any indication that age differences in memory might be qualitative. The substantial benefit in the next interval (lag 25

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[2] Only 2 subjects (both young women) hit ceiling for total corrected recognition scores, but many had ceiling scores (12/12) in one or more of the 8 cells (3 lag × 2 codability + 2 one-occurrence cells). Of 384 possible ceiling scores in each age group (48 subjects × 8 cells), young adults had 185 (48.2%) compared with 115 (29.9%) in the older group. In the younger group, codability made no difference in ceiling rates (low = 91, high = 94), but the older group had a much lower rate for high-codability items (low = 75, high = 40).

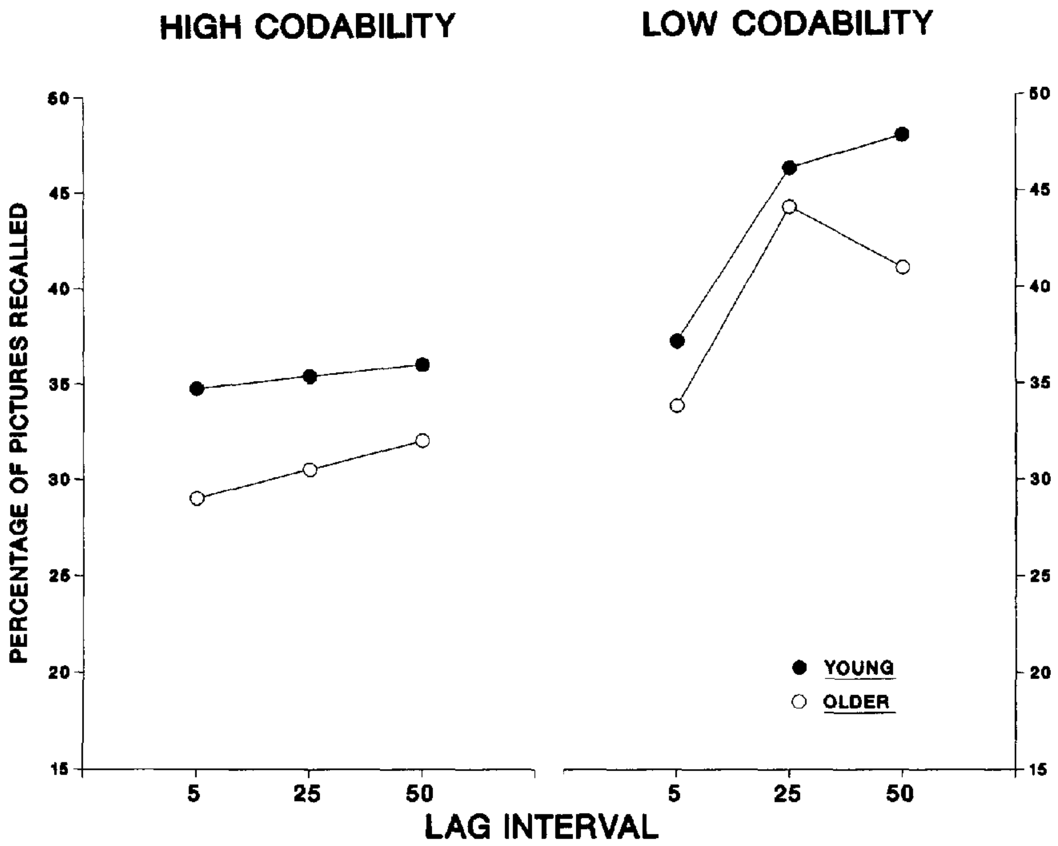

Figure 3. Mean percentage of pictures recalled as a function of lag, codability, and age group.

to lag 50) suggests that the data in the 5- to 25-interval may be spurious.

In summary, the recognition data generally replicate the free recall data, insofar as basic main effects are concerned. Codability, lag, and repetition manipulations resulted in the same outcomes for both measures of episodic memory. Likewise, age effects were similar, in spite of a greater incidence of ceiling effects in younger adults. The younger group's ceiling effects could have attenuated age differences, but this did not happen. In fact, age differences are likely to have been even larger without ceiling effects. It is impossible to interpret the ostensible interactions, but generally the age differences again seem to be quantitative, rather than qualitative. That is, older adults demonstrate reliable differences in episodic memory relative to younger adults, but the way in which the memory processes operate generally appears to be unaffected by normal aging.

Factor Analysis

One final approach to the search for different types of memory was undertaken through factor analysis. If these measures are indeed tapping separate memory systems, then they should load on separate factors. A principal components factor analysis was conducted on the following 11 variables: (1) total free recall score, (2) total corrected recognition score, (3) recall slope as a function of 1-min periods, (4) number of intrusions in free recall, (5) repetition priming (difference between repeated and baseline items in milliseconds), (6) lag effect (decay between low-codability lag-25 and lag-50 items in milliseconds), (7) total naming consistency score, (8) codability effect (low − high codability latency on first occurrences), (9) number of TOTs, (10) number of naming (commission) errors, and (11) WAIS—R Vocabulary scores. Items 1–4 were assumed to be episodic measures, items 5–6 procedural, and items 7–11 semantic. The analysis was conducted with all subjects combined in order to ensure an adequate sample size and variance.

Four factors had eigenvalues greater than 1, but the scree plot indicated three dominant dimensions. A varimax rotation was therefore performed on both the three- and four-factor solutions. The two solutions were very similar, and the only significant difference was that name consistency defined its own factor in the four-factor solution. Because singlet (single marker) factors are mathematically and psychologically suspect (cf. Guilford, 1952), the three-factor solution was retained as the final structure.

The rotated factor matrix is presented in Table 6. The three factors accounted for 21.8%, 18.7%, and 14.6% of the variance, respectively. Factors 1, 2, and 3 can be interpreted most parsimoniously as episodic, procedural, and semantic mem-

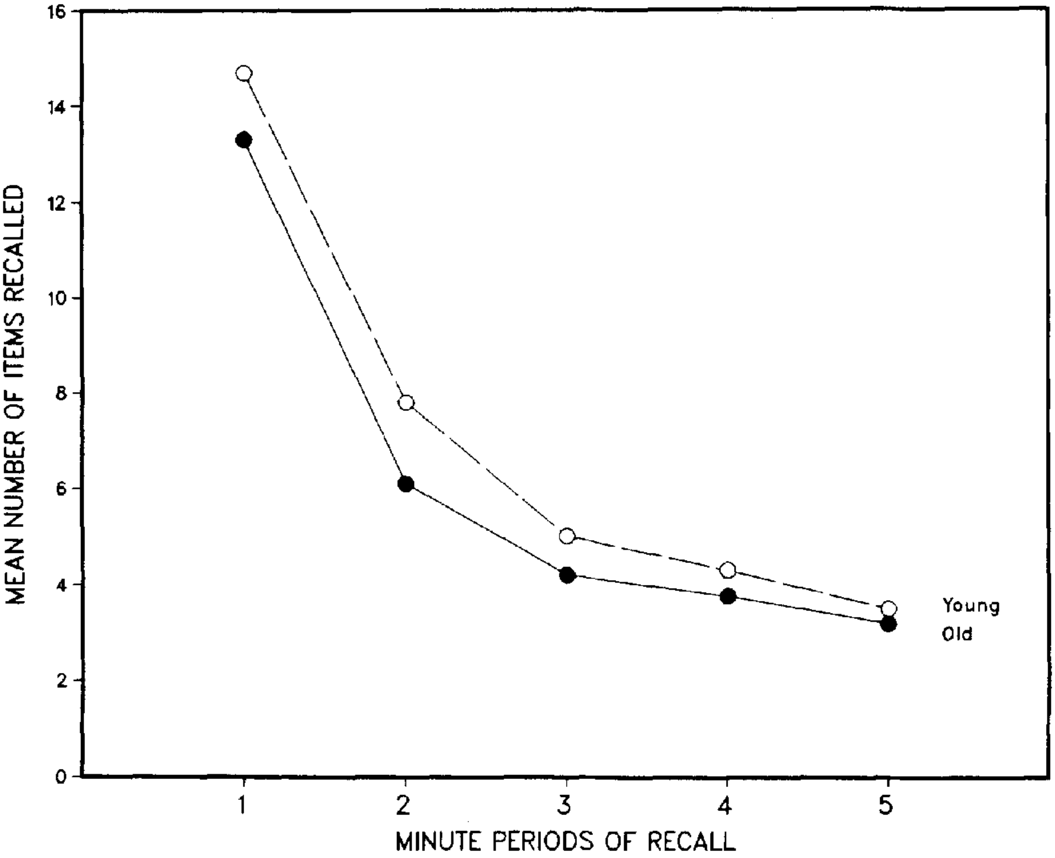

Figure 4. Mean number of pictures recalled as a function of five 1-min periods for young and older subjects.

ory, respectively. Only name consistency, thought to tap semantic memory, did not load strongly on any factor.

The factor analysis, like age-group differences, clearly differentiates episodic from semantic memory components. There is also strong evidence for a third and distinct component. Whether or not this third factor actually constitutes Tulving's (1983, 1985) concept of procedural memory is more problematic. Two of the three measures that loaded on this factor were predicted to tap procedural memory, but the third (codability effect) was designed to tap semantic memory. What the three measures have in common is that they are all measures of retrieval efficiency. Although retrieval efficiency measures were used because of their theoretical independence from general processing speed, an additional analysis with base-rate naming latency included revealed that this measure also loaded (.84) on the same factor. All of the measures that loaded on either episodic or semantic components were accuracy measures. Thus, future research should include additional accuracy measures for procedural memory (e.g., word fragment completion, picture or word identification) as well as efficiency measures (e.g., latencies) for episodic and semantic memory.

Discussion

The results from the present investigation supply further evidence of dissociations between different types of memory tasks. Three types of dissociations were seen. First, older adults' memory performance was not globally impaired in comparison with that of younger adults but rather was limited to one class of tasks tapping episodic memory. No significant age-related impairments were evident for measures of either semantic or procedural memory. Second, the manipulation of stimulus codability produced a functional dissociation: With lower codability, semantic retrieval worsened whereas both procedural priming and episodic retrieval improved. Third, a principal components analysis revealed that 10 different measures loaded distinctly on three separate factors. The types of tasks that loaded on each of the three factors generally corresponded to Tulving's (1985) concepts of episodic, semantic, and procedural memory.

Memory Distinctions Supported by Age Difference Patterns

The age difference patterns provide a good basis for distinguishing episodic from both semantic and procedural memory. First, reliable age differences were found in recall and recognition performance. Second, although intrusions and repetitions during recall were relatively low in frequency, older adults as a group had a higher incidence of these episodic difficulties as well. In contrast, almost all other measures revealed no age-related memory deficits. Older adults did

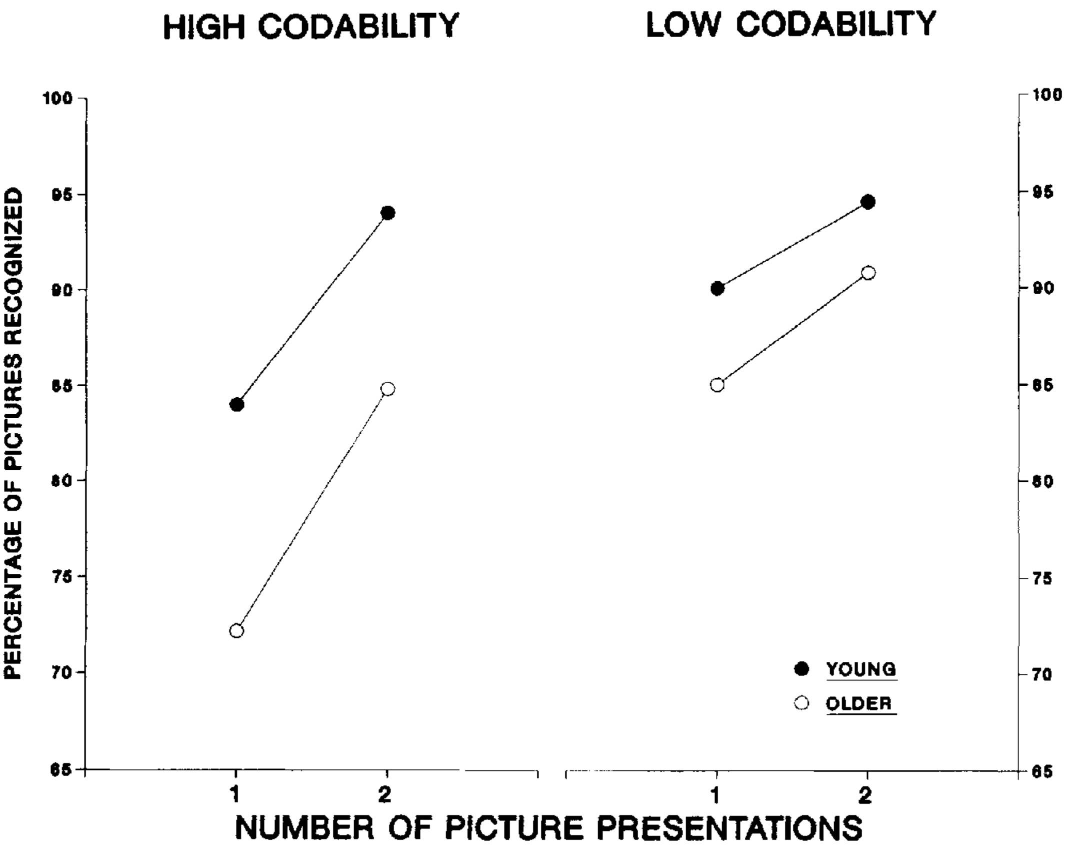

Figure 5. Mean percentage of pictures correctly recognized as a function of repetition, codability, and age group.

have slower naming latencies, reflecting a general slowing of peripheral processes. However, their latency difference scores, thought to reflect more central processes such as retrieval efficiency, were virtually identical to those of the young adults. In fact, their lag effects were slightly smaller than those of the young adults, suggesting a slower decay rate in priming. Codability could be expected to produce steeper differences in older adults based on findings that their reaction times generally increase disproportionately with increases in "processing complexity" (cf. Salthouse, 1985). Yet, the older adults' codability difference scores were not reliably different from those of the young. Likewise, measures of naming consistency, naming errors, and TOTs revealed that the older group's semantic memory functioning was not unlike that of the younger adults. Furthermore, in spite of older adults' lower episodic performance, their vocabulary scores were superior to those of the young adults. This suggests that retrieval processes in general are not impaired but rather that episodic memory retrieval in particular is.

There was a small but nonsignificant age difference in repetition priming, replicating recent research in procedural memory and aging (see Table 1). As Light and Singh (1987) pointed out, it is possible that our measures of repetition priming are not sensitive enough. On the other hand, if the age effects continue to flip-flop nonsignificantly in emerging research, then we can be more comfortable in concluding an absence of age effects. In Table 1, nine studies favor younger and five favor older adults. In the current investigation, the two priming effects were split, one favoring the young and the other favoring the older adults.

The lack of age differences in either naming accuracy or retrieval efficiency is particularly interesting in light of studies that have reported age-related deficits in retrieving specific object names from semantic memory (see Obler & Albert, 1985). The stimuli used in the present study probably contained a higher proportion of more common objects than those represented in the Boston Naming Test (e.g., *trellis*, *yoke*), which was used in the studies reviewed by Obler and Albert. In a similar vein, Bowles and Poon (1985) used Brown's (1979) retrieval blocking paradigm and found that older adults revealed greater inhibition in retrieving a specific word given a cue, relative to young adults. In contrast, age differences are not found in retrieval facilitation, either as a function of repetition or associative priming. If it is true that aging affects semantic inhibition but not facilitation, this would appear to be a dissociation within semantic memory. However, Tulving (1983) pointed out that priming (i.e., semantic facilitation following a single exposure) is actually a "phenomenon of procedural memory" (p. 109). Is semantic inhibition procedural or purely semantic? The only thing that is clear is that the roles of semantic inhibition and facilitation in relation to aging need further investigation.

The episodic measures were clearly distinguished from all other measures. However, the present age difference patterns

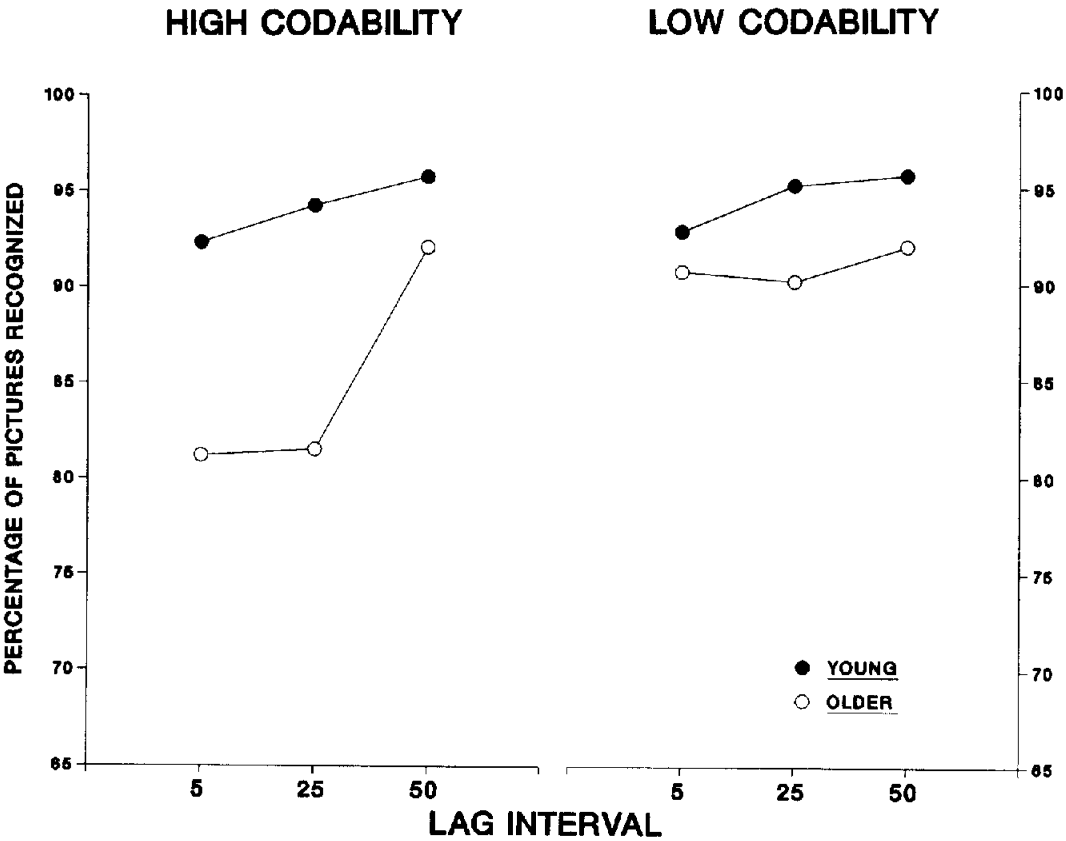

Figure 6. Mean percentage of pictures correctly recognized as a function of lag, codability, and age group.

per se provide no basis for distinguishing between semantic and procedural memory. Because normal aging does not seem to impair either of the two lower systems in Tulving's (1985) monohierarchy, it is necessary to find subjects who have problems with both episodic and semantic memory. Tulving's monohierarchical principle predicts that individuals could suffer impairments in both upper systems without damage to the lowest, procedural memory. Indeed, Tulving's model receives some support from recent research on Alzheimer's disease patients. These individuals experience problems with both episodic and semantic memory (e.g., Mitchell, Hunt, & Schmitt, 1986; Weingartner et al., 1983) and yet reveal normal procedural memory functioning in tasks such as repeated picture naming (Mitchell & Schmitt, 1988) and reading inverted text (Moscovitch, Winocur, & McLachlan, 1986). On the other hand, in spite of major semantic retrieval problems, intact associative and contextual priming has been reported in Alzheimer patients (Nebes, Boller, & Holland, 1986; Nebes, Martin, & Horn, 1984). If semantic access but not semantic activation is impaired, then some distinctions within semantic memory may be necessary. Research activity is very high in this area, and in a few years a better picture of the various memory systems in dementia should emerge.

Table 6
Factor Matrix

Variable	Factor 1	Factor 2	Factor 3
Free recall	**.75**	.08	−.06
Recognition	**.81**	.04	−.16
Recall slope	**−.69**	−.08	−.01
Recall intrusions	**−.53**	.25	−.26
Repetition priming	.20	**.81**	.16
Lag effect	−.20	**.52**	−.10
Codability effect	.05	**.92**	.03
TOT responses	.00	−.10	**.82**
Naming errors	−.32	.34	**.71**
WAIS—R Vocabulary	−.07	.00	**−.63**
Name consistency	.36	−.26	−.01

Note. Factor 1 = episodic memory; Factor 2 = procedural memory; Factor 3 = semantic memory. TOT = tip of the tongue; WAIS—R = Wechsler Adult Intelligence Scale—Revised.

Memory Distinctions Supported by Experimental Manipulations

Codability produced a dissociation between semantic and episodic performance. Low-codability pictures, relative to high-codability ones, produced both both slower retrieval from semantic memory (cf. R. Lachman & Lachman, 1980) and more errors (commission and TOTs). In contrast, low-codability pictures yielded better episodic-memory performance. This particular dissociation has not been reported previously. The superior recognition of low-codability pictures is not surprising given their relatively lower frequency. The higher recall of low-codability pictures, however, seems puzzling because the frequency effect is usually reversed for episodic recall of words (i.e., high frequency produces higher recall; cf. Mandler et al., 1982). One possibility is that naming a low-codability picture entails a relatively deeper level of processing, whereas this is not a concomitant in reading a low-frequency word. This explanation fails, however, because the low-codability advantage in recall occurred only for repeated pictures and not for those named once (see Figure 2). An alternative account is that the greater priming that occurred for repeated low-codability pictures (see Figure 1) reflects greater activation of those items, making them relatively more accessible for recall. Indeed, Jacoby and his colleagues (Jacoby & Dallas, 1981; Jacoby & Hayman, 1987) have shown that a single presentation of a low-frequency word increases the probability of later perceptual identification to a level equal with that of high-frequency words. In other words, a low-frequency item takes a quantum jump in accessibility following a single encounter. Perhaps the repetition of a high-codability item is relatively less beneficial because the accessibility of that item is already near some optimum level.

The lag effect (cf. Glenberg, 1977) was replicated in both recall and recognition, such that performance generally increased as a function of longer intervals. Lag produced the opposite effect on the magnitude of repetition priming, which decreased over longer lags (replicating Durso & Johnson's results, 1979). Although this might appear to be a double dissociation between episodic and procedural memory, lag and retention interval were, unfortunately, confounded in the two measures. That is, lag during naming constituted spacing for the episodic retention tests, but lag was no more than variations in retention interval for repetition priming. Thus, it is not possible to evaluate the apparent lag by task dissociation. In studies with longer retention intervals, however, in which the two are not confounded, dissociations have been reported. For instance, Mitchell and Brown (1988) found that recognition memory for pictures declined systematically across 1 to 6 weeks, whereas repetition priming remained stable. Tulving, Schacter, and Stark (1982) reported a similar dissociation between word-fragment completion and recognition over a 1-week interval.

There was no clear dissociation between semantic and procedural memory as a function of either lag or codability. This dissociation is empirically infrequent because most procedural tasks require retrieval from semantic memory, even though conscious episodic recollection is not required. Such a dissociation has been reported, however, in a lexical decision task. Semantic priming (e.g., *mouse–cheese*) was found to vanish beyond a zero-lag interval, whereas repetition priming (e.g., *mouse–mouse*) remained viable after a 64-item lag (Dannenbring & Briand, 1982). Indeed, repetition priming in words and pictures survives very long intervals ranging from 6 weeks to 16 months (Kolers, 1976; Mitchell & Brown, 1988; Sloman, Hayman, Ohta, Law, & Tulving, 1988). Semantic priming in picture naming has been reported (Sperber, McCauley, Ragain, & Weil, 1979), but the effect of retention interval has not been investigated.

Memory Distinctions Supported by Factor Analysis

The outcome of the principal components analysis was unambiguous at one level: Three distinct factors emerged. The semantic and episodic factors were certainly clear-cut in terms of the measures that loaded on them. A similar approach to the structure of memory tasks undertaken by Underwood et al. (1978) also revealed, in their words, that "episodic memory tasks and the semantic memory tasks represent two different worlds" (p. 409). Their investigation, however, included no measures of procedural memory.

The factor labeled procedural memory begs for scrutiny. Is this factor no more than a collection of speed-of-response measures? All of the latency measures loaded on this factor, including one that theoretically should not, semantic retrieval efficiency. Furthermore, as mentioned previously, base-rate naming latency also loaded on the same factor in a subsequent analysis. Unfortunately, no accuracy measures of procedural memory were used in this investigation. Thus, although this factor may include the stuff that procedural memory is made of, the most parsimonious interpretation is that this factor represents a general speed or efficiency parameter.

An alternative account of the three factors would suggest that they were not produced by three memory systems but by three different types of memory demands. For instance, it could be argued that Factor 1 is based on delayed memory tests, Factor 2 is based on response speed measures, and Factor 3 is a product of vocabulary skills. At one level, the labels may just be a matter of semantics. But at another level, the question of how many memory systems there are is a critical one for memory theory. As Neely (in press) pointed out, claims about separate memory systems must be based on data from measures that are not confounded with other factors. In the current investigation, procedural memory was assessed solely with latency or efficiency measures, whereas all of the episodic measures were accuracy measures. Semantic versus episodic comparisons did not suffer from this confound.

Thus, future research on the issue of multiple memory systems must include, in a single investigation, many measures attributed to procedural memory (homophone spelling, fragment completion, perceptual identification of words and pictures, etc.) to see how they hang together. Both efficiency and accuracy measures must be taken. If factors emerge based on efficiency versus accuracy measures rather than on episodic versus procedural ones, the case for multiple memory systems could be weakened. Such a conclusion from the present data would be premature, however, because none of the accuracy measures seemed to tap procedural memory.

One or Many Memory Systems?

Do the present findings offer evidence for more than one memory system? On the basis of the variety of dissociations observed, the data are certainly consistent with a multiple memory model. However, the data may also be interpreted as a reflection of encoding–retrieval interactions (Jacoby, in press) or transfer appropriate processing (Roediger & Blaxton, 1987). For instance, Weldon and Roediger (1987) showed that procedural memory performance was best for previously seen pictures when picture fragments were used, whereas performance was best for words when word fragments were provided. As in this example, a transfer-appropriate-processing point of view stresses the match between the retrieval test and the encoding episode.

Although the importance of the study and test modes for memory performance cannot be underestimated, this point of view cannot account for the present data. In particular, the fact that older adults performed less well than young adults only on one class of tasks (episodic) points to something in the memory system. Because both young and older adults processed the same stimuli and completed the same tasks, the question of encoding-retrieval matches is irrelevant. A unitary memory point of view (e.g., McKoon et al., 1986) is also unsatisfactory, because a single memory system—to make a parsimonious assumption—should age uniformly, not selectively. Thus, older adults would be expected to exhibit lower levels of performance on all kinds of memory tasks, not just one type. On the other hand, if there are separate memory systems, some could be affected by aging and some could be spared. This seems to be the case. Furthermore, even if research demonstrates *some* semantic retrieval deficits associated with old age, to the extent that these deficits are fewer and of a lesser magnitude than the large number already documented in episodic memory, the monohierarchical ordering of relative deficits (i.e., greatest in episodic, some in semantic, least in procedural) would still hold. Finally, the theory of separate memory systems is also consistent with findings that amnesic patients also reveal selective, not global, memory impairments.

If it is true that there is more than one memory system, how many are there? That there may be at least two is further supported by the plethora of different labels in the literature that are analogous to Tulving's (1985) distinctions between episodic and procedural memory (cf. Cohen & Squire, 1980; Graf & Schacter, 1985; Jacoby & Brooks, 1984; Schacter, 1987). In addition, debate about the episodic–semantic distinction continues (cf. Johnson & Hasher, 1987) 15 years after its introduction. The distinction between semantic and procedural memory has received little attention so far, but that is likely to change. Whether there are two, three, or even more systems remains the multiple question of choice in contemporary memory research.

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