

Adult Age Differences in Memory Performance: Tests of an Associative Deficit Hypothesis

Moshe Naveh-Benjamin
Ben-Gurion University of the Negev

An associative hypothesis to explain and predict older adults' deficient explicit episodic memory performance was outlined and tested. The hypothesis attributes a substantial part of older adults' deficient memory performance to their difficulty in merging unrelated attributes—units of an episode into a cohesive unit. Although each of the components can be memorized to a reasonable degree, the associations that tie the attributes—units to each other grow weaker in old age. Four experiments are reported that provide (a) a converging validity to the hypothesis by demonstrating this associative deficit for both interitem relationships and intraitem relationships and (b) a discriminant validity to the hypothesis by contrasting and testing competing predictions made by the associative hypothesis and by alternative hypotheses. The implications of these results to older adults' episodic memory performance are discussed.

The ability to learn new information and retrieve previously learned information is essential for successful aging. It allows older adults to adapt to changes in their environment, social roles, and self-concept. Memory researchers interested in life-span development have attempted to explain adult age differences in memory performance with the aim of both increasing our understanding of older adults' behavior and establishing a knowledge base that will constrain memory theories in general. Several hypotheses have been advanced to explain the relatively poor memory performance of older adults, including a deficit in semantic processing, a failure of metamemory, a failure of deliberate recollection, a reduction in processing resources (see Light, 1991, for a review), and a failure of inhibitory processes (Hasher & Zacks, 1988). Although all of the above are related to older adults' memory deficits, especially those deficits that characterize episodic memory, none of them provide an explanation for the full range of phenomena associated with older adults' episodic memory deficits.

Chalfonte and Johnson (1996) have suggested that part of older adults' deficient memory performance stems from their difficulty in binding the information into complex memories (see also Gilbert, 1941; Light, 1992; and MacKay & Burke, 1990). The present study extended this suggestion by testing an associative deficit hypothesis (ADH) that focused on the distinction between memory

for single units and memory for association among units. This hypothesis claimed that an important component of older adults' poorer episodic memory is their deficiency in creating and retrieving links between single units of information. The basic units can be two items; an item and its context; two contextual elements; or, more generally, the representation of two mental codes. The extent to which a given memory task requires the creation or use of such associations is a significant determinant of older people's memory performance.

The purpose of this study was to determine the possible implications of this hypothesis on the memory performance of older adults and to experimentally demonstrate some of its critical predictions. This was done (a) by demonstrating an associative deficit in two experiments, each of which used different tasks that required processing both single units and their association to each other, and (b) by contrasting, in two further experiments, predictions based on an ADH with ones made by other current hypotheses.

Demonstration of the Utility of an ADH

Complex events consist of multiple kinds of information sources that are related together. An event can include the semantic content, information about the time in which the event occurred, the place in which it took place, the acting agents, their characteristics, and so on. All of these aspects integrated with the internal cognitive state of the person are encoded as an episode. Remembering such an episode requires that at least some of the components be retained, as well as their relationships with each other.

In the literature, different types of associations were, for the most part, treated separately (but see Chalfonte & Johnson, 1996; Johnson, 1992; and Johnson, Hashtroudi, & Lindsay, 1993, for a different view). For example, the relationships of two messages were treated within a paired-associates paradigm. The relationships of a message and a voice were treated as memory for context. Finally, memory for a message in a specific time and place was investigated as memory for source. All of these examples, how-

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Correspondence concerning this article should be addressed to Moshe Naveh-Benjamin, Department of Behavioral Sciences, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. Electronic mail may be sent to naveh@bgumail.bgu.ac.il.

ever, constitute the establishment of connections among single units at one level or another.

There have been several suggestions in the literature that are in line with a separation within memory of information about single units from information about associative relationships among these units (e.g., Anderson & Bower, 1973; Chalfonte & Johnson, 1996; Gillund & Shiffrin, 1984; Humphreys, 1976; Johnson, 1992; Johnson & Chalfonte, 1994; Murdock, 1982, 1993). This distinction between item and associative information has been supported by several experiments that yielded different patterns of results for the two types of information (e.g., Doshier, 1988; Gronlund & Ratcliff, 1989; Hockley, 1991, 1992, 1994; Hockley & Cristi, 1996).

The research literature on memory and aging has concentrated on memory for items and memory for relationships among items. However, most of this research has treated each type of memory individually. When these types of memory are compared directly, it is almost always not as a way of specifying differential mechanisms but in a context of a comparative task performance, with item memory mostly serving in recognition paradigms and associative memory serving in paired-associates and free-recall paradigms.

Item memory has mostly been studied using a recognition paradigm. When younger and older participants are compared in such a paradigm, the standard effects obtained reflect a moderate disadvantage for older people (e.g., Gordon & Clark, 1974). This relative sparing of recognition memory has been contrasted with appreciable deficits in older people's free-recall performance, assumed to require associative processing in order to relate the items to each other (Craik, 1986; Craik & McDowd, 1987).

One way to resolve these differential effects of age on recognition and free-recall performance is to claim that recognition memory is mediated by item information, whereas free recall is mediated by associative-relational information (Mandler, 1979).¹ This comparison of recognition and free recall in younger and older people, however, involves a multitude of factors and can not provide a clear-cut indication of the relative sparing of item information accompanied by a more marked decline in memory for associative information in older people. For example, older people may be disadvantaged in the initiation of memory search that characterizes free recall, and this has little to do with associative disadvantage.

A different comparison may be suggested that involves the use of a recognition task to assess memory for item information with a cued-recall (paired-associates) task that requires associative information. Inspection of the literature reveals significant age-related differences in paired-associates learning (e.g., Gilbert, 1941; Korchin & Basowitz, 1957; Kausler & Puckett, 1980; Ruch, 1934). However, the comparison of younger and older adults on recognition and cued-recall tasks might not provide the best indication for differential age-related effects on item and associative information as these two tasks may differ in other aspects as well (e.g., differences in the forced nature of the response).

If one wants to compare directly memory for item and associative information, one needs to choose two tasks that require those processes, with only one difference: Whereas one task requires the encoding and retrieval of associative information, the other requires the encoding and retrieval of item information. In addition, to attribute the difference between item and associative information mostly to encoding, tasks must be chosen that minimize

retrieval effects. One procedure that applied this method is the one used by Humphreys (1976) and Glenberg and Bradley (1979). Under this procedure, participants study a list of pairs of items. For item information, participants receive at test some of the original items with some new items and their task is to recognize the old items. For associative information, participants receive some originally intact pairs, which appeared as pairs at the study phase, and some recombined pairs, which include items that were presented but now Item A is taken from one pair and Item B from a different pair. Participants have to recognize which of the pairs appeared as such originally. Participants in such a procedure encode the same information during the study phase, and during the test phase they are provided with all of the information in both tests; hence, the differences in performance between the two tests reflect differential memory for item and associative information.

Although such a procedure has been used in the literature on younger adults (e.g., Glenberg & Bradley, 1979; Humphreys, 1976), and more recently to specifically address questions concerning the relationships of item and associative memory (e.g., Hockley, 1991, 1992; Hockley & Cristi, 1996), it has not been used to directly compare younger and older adults (but see Chalfonte & Johnson, 1996, for a somewhat similar procedure, detailed below). As mentioned above, the studies with younger participants established different patterns of performance for item and associative information.

In the first experiment, I assessed the degree to which old age differentially affects memory for associative and item information. The type of association used in this experiment was the episodic relationships established between two unrelated items that appeared together (intermit associations). Unrelated word-nonword pairs were presented to younger and older adults for study under instructions to learn for upcoming memory tests. Item memory was tested by a recognition test in which half of the items (either the words or the nonwords) were studied (targets) and half were not (distractors). Associative memory was tested by presenting participants with target items only, either as intact pairs (a word and a nonword that were presented together at study) or as recombined pairs (a word and a nonword presented in different pairs at study), and asking them to recognize the intact pairs. The ADH predicted an interaction between age and type of test. Specifically, the differences between younger and older adults were expected to be the greatest in the word-nonword association test.

Experiment 1

Method

Participants. Participants were 20 younger and 20 older adults. The younger participants were undergraduate students at Ben-Gurion University of the Negev who participated in the experiment as part of their course requirements. The older participants were residents of Beer-Sheva who lived independently in the community. The mean age, education level, and male:female proportion for each age group in each of the experiments reported in this article appear in Table 1. In this experiment, as in the other

¹ As noted by one of the reviewers, Mandler's (1979) use of the term *association* may be more general than its use in this article. The distinction used in this article may be conceptualized as association-specific versus item-specific information.

Table 1
Mean Age, Number of Years of Formal Education, and Male:Female Proportion for Each of the Younger and Older Adult Groups in the Four Experiments

Experiment	Age (years)				Education (years)				Male:female proportion	
	Younger adults		Older adults		Younger adults		Older adults		Younger adults	Older adults
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
1	22.4	1.9	72.1	5.0	12.3	1.6	12.1	2.9	.40	.35
2	22.0	2.5	71.1	5.2	12.5	1.6	12.3	3.3	.55	.58
3	22.4	2.9	74.1	6.1	12.7	0.9	12.1	3.1	.35	.38
4	22.1	2.6	72.2	4.9	12.4	0.7	12.2	3.1	.32	.35

three experiments reported in this article, there were no differences between the younger and older adults in level of formal education or male:female proportion. All of the older participants in all of the experiments reported being in good health and having good hearing and vision.

Design. Two independent variables were used: age (young vs. old; between subjects) and test (words, nonwords, and words + nonwords; within subjects).

Materials. The study phase included presentation of 40 word-nonword pairs on index cards.² Each pair was presented at the same vertical level, with five horizontal spaces between the word and the nonword. The first 6 pairs served as practice. Of the next 34 pairs, 4 (2 at the beginning and 2 at the end) were used as buffers. The remaining 30 pairs served as the experimental stimuli. Words were high-frequency two- and three-syllable Hebrew nouns taken from Balgur's (1968) norms. Each nonword was created by swapping letters of a word not included in the words sample. The resulting nonwords were all pronounceable and similar in length to the words. The word and the nonword in each pair were unrelated to each other acoustically or structurally. Words and nonwords belonging to different pairs were also unrelated to each other in any apparent way. Two random versions of word-nonword pairings were created, and two random orders were used for each of these pairings to create four versions. Five younger participants and 5 older ones were run in each version. The distractor items in the word and nonword tests were 20 words or nonwords, respectively, with the same characteristics as the targets.

Procedure. Participants who were tested in groups of 2 to 3 saw a list of word-nonword pairs presented sequentially. They were told to study them in preparation for the upcoming item and associative recognition tests, the nature of which was explained.

The word-nonword pairs were presented sequentially at a pace of 1 pair every 10 s. After presentation of the first 6 pairs, which were used for practice, three short tests were given. In the word recognition test, two target words (one from each of 2 pairs) and two distractors (new words) were given. Likewise, in the nonword recognition test, two nonword targets (one from each of 2 pairs) and two distractors (new nonwords) were given. The pair recognition test included 2 intact pairs and 2 recombined pairs. Any questions that participants had were answered before the next phase started, in which participants were presented with the 34 experimental pairs, 1 at a time without a pause.

After the end of the study phase, participants had to count backward by threes for 90 s as an interpolated activity. Then the three memory tests listed below, one for words, one for nonwords, and one for their associations, were administered to all of the participants. The order of the tests was counterbalanced across all of the participants, resulting in 3 or 4 participants in each age group serving in each of the six orders. Each word, nonword, or word-nonword pair appeared in only one of the tests. This was done to avoid across-tests item reexposure effects.

1. *Word recognition test.* In this test, participants received a page

with 20 words (10 targets and 10 distractors), which were mixed randomly. For each participant, targets were selected at random from 10 of the studied pairs, 1 from each pair. The distractors were 10 words with the same characteristics as the target words but did not appear in the study phase. Participants were told that 10 of the words appeared in the study phase and were instructed to circle those words.

2. *Nonword recognition test.* In this test, participants received a page with 20 nonwords (10 targets and 10 distractors), which were mixed randomly. For each participant, targets were selected at random from 10 of the studied pairs, 1 from each pair. The distractors were 10 nonwords with the same characteristics as the target words but did not appear in the study phase. Participants were told that 10 of the nonwords appeared in the study phase and were instructed to circle those nonwords.

3. *Associative recognition test.* In this test, 20 word-nonword pairs appeared, selected randomly for each participant. Ten of them were intact pairs from the study phase (i.e., pairs that appeared together in the study phase). The other 10 pairs were recombined (rearranged) pairs (i.e., they were composed of words and nonwords taken from different study pairs). None of these words or nonwords appeared in the item recognition test. Participants were told that all of the items appeared in the study phase and that their task was to circle the 10 pairs that appeared as such in the study phase. Participants had as much time as they needed to complete all of the memory tests.

Results

Because some of the participants in both age groups did not indicate the suggested number of words as targets (they indicated too many or too few), measures of proportion of hits minus false alarms were computed for each participant and then averaged over each age group for every test. This equated the word, nonword, and the associative recognition tests with respect to the scale used (from chance level performance at 0.0 to highest possible score at 1.0). In addition, the three tests used were of comparable discriminating power, as indicated by the similar variability of performance in the three tests, allowing their direct comparison as

²The use of different presentation rates in some of the experiments, different numbers of stimuli during the learning phase in each of the experiments, and different numbers of test items within and between experiments was a result of pilot studies. The actual number of stimuli for each experiment was determined in order to avoid ceiling effects in the younger adults and floor effects in the older adults and to create for each experiment scales of similar sensitivity for both the younger and older adults.

three levels of the test variable (for this and the following experiments). Finally, because a preliminary analysis of variance (ANOVA) indicated no interaction effect of order of the administration of the tests with any of the independent variables, in all of the following reported analyses (for this and the following experiments), performance was collapsed across the different orders.

Figure 1 presents results for the proportion of the hits minus false alarm measure in the different conditions. A 2 (age) \times 3 (test) mixed factorial ANOVA was performed on the corrected hit rates (the .05 level of significance was used to interpret all of the statistical comparisons). The effect of age was significant, $F(1, 38) = 33.92$, $MSE = 0.038$, where the younger adults (.49) performed better than the older adults (.29). The effect of test was also significant, $F(2, 76) = 50.24$, $MSE = 0.013$. Follow-up contrasts analysis (see Keppel, 1982) showed that performance in the word test (.52) was significantly better than performance in the nonword test (.32), which, in turn, was not different from performance in the word-nonword association test (.33), $F_s(1, 38) = 72.70$ and 0.46 , respectively.³ Most important for the purpose of the present study, the interaction of age and test was significant, $F(2, 76) = 27.98$, $MSE = 0.013$. Follow-up contrasts indicated that the source of this interaction was the different patterns obtained for each test. There were significant differences between the younger and older adults in the word-nonword association test (for younger adults, $M = .51$; for older adults, $M = .15$), $F(1, 38) = 66.71$, and in the nonword test (for younger adults, $M = .43$; for older adults, $M = .20$), $F(1, 38) = 35.90$, but not in the word test (for younger adults, $M = .53$; for older adults, $M = .50$), $F(1, 38) = 0.27$. To assess the relative deficit of the older adults in the word-nonword association test, a follow-up interaction comparison (Keppel, 1982) was conducted, which indicated that age differences were greater in the word-nonword association test than in the nonword test, $F(1, 38) = 12.35$, $MSE = 0.005$. The

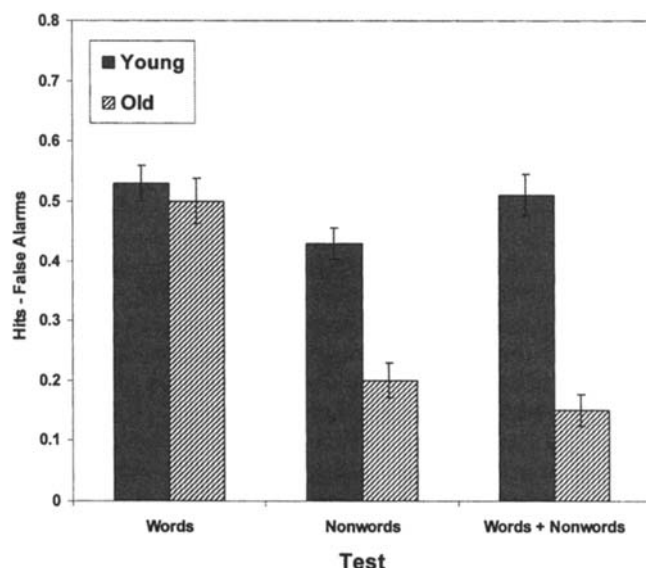


Figure 1. Proportion of hits minus proportion of false alarms (\pm SEs) in the item (words, nonwords) and associative (words + nonwords) recognition tests for the younger ($n = 20$) and older participants ($n = 20$) in Experiment 1.

same patterns were found when age effects, computed as the difference between the means of the younger and older adult groups in a given condition/test, were computed. The age effects for all of the experiments reported in this article appear in Table 2.

The performance of the older adults in all of the tests was significantly better than chance (.00).

One reservation regarding the above-reported results is that there were quite sizable age differences on at least some of the elements that entered into the associations. In particular, the fact that the younger and older adults were not equated on nonword memory could have contributed to the observed larger age-related differences in associative information. To rule out this possibility, an analysis of covariance (ANCOVA) was performed, which allows the evaluation of age differences on one measure of performance while controlling statistically (equating) age differences in memory for another. Specifically, to establish differential effects of age on the different memory tasks, an ANCOVA was performed to inspect age differences in associative recognition when both word and nonword recognition scores were taken as the covariates. Such a method was used by Craik and McDowd (1987) to establish differential effects of age on different memory tasks.⁴

To use an ANCOVA, I checked whether there were any violations of the assumption regarding the homogeneity of the regression slopes. To do so, I calculated for each age group the regression slope relating each of the covariates (word and nonword recognition) to the dependent measure (associative recognition). The resulting slopes for each covariate were compared with each other using t tests; none of the comparisons were statistically significant ($p > .05$), indicating no violation of the assumption. Therefore, an ANCOVA was performed with age as the independent variable and word and nonword recognition as the covariates. The analysis yielded an adjusted mean associative recognition score of 0.42 and 0.24 for the younger and older participants, respectively. These age differences were statistically significant, $F(1, 36) = 14.49$, $MSE = 0.01$, indicating that the older adults had a deficit in the associative recognition test above and beyond that in the item recognition test.

Discussion

The corrected hit measure (hits minus false alarms) indicated several patterns. Most importantly, as indicated by the significant interaction of age and test, the older adults showed a differentially poorer performance in recognition of associative information compared with the younger adults. Apparently, despite the fact that the older adults stored word information as well as the younger adults,

³ These results, which indicate better recognition memory for word than for nonword information, might be related to the specific words and nonwords used in this experiment. Other patterns, like better recognition performance for nonwords, may be obtained. This could occur when nonwords are better distinguished from one another than words. A similar case is that of low-frequency words, which occasionally are better recognized than high-frequency ones.

⁴ Note that the present use of an ANCOVA differs from more traditional treatments of this procedure, which usually entail measuring the covariate prior to the experiment. The present use is equivalent to a parallel multiple regression analysis, and steps have been taken to ensure that the assumptions underlying the use of an ANCOVA were met, as described in the text.

Table 2
Means of the Age Effect in Memory Performance (the Difference Between Means of the Hits Minus False Alarms of the Younger and Older Adult Groups in a Given Condition/Test) in the Different Conditions of the Four Experiments

Experiment 1			
Recognition test			
	Word	Nonword	Word + nonword
	.03	.23	.36
Experiment 2			
Recognition test			
Study instruction	Item	Associative	
Words	.12	.19	
Pairs	.13	.41	
Experiment 3			
Recognition test			
Study instruction	Word	Font	Word + font
Words	.03	-.02	.24
Fonts	-.05	.04	.22
Words + fonts	.02	.01	.34
Experiment 4			
Test			
Types of pairs	Free recall ^a	Cued recall ^a	Recognition ^b
Unrelated	.17	.33	.10
Related	.04	.03	-.01

^a Based on percentage correct. ^b Based on percentage of hits minus false alarms.

they did not encode and store associative information (in this case, between word and nonword pairs) as well as the younger adults. The older adults also showed an appreciable deficit in their memory for nonwords, although it was smaller than their deficit in memory for the associations. This deficit in the recognition of nonwords could be accommodated by the ADH as the older participants could not assimilate in any obvious way these nonwords into preexisting knowledge; apparently, they attempted, and failed, to create new associations among the letters of each nonword.

This latter result, however, raises the possibility that the older adults' poorer associative memory in this experiment was due, at least in part, to their very poor memory for the nonwords. If this is true, then the poorer nonword memory of the older adults did not allow them to appropriately create associative relationships between the components (the words and the nonwords), relationships that were created by the younger adults, as they encoded well both components. To rule out this possibility, in the second experiment, the associated pairs included words only to ensure that the associative deficit that the older adults exhibited was not due to their marked poor memory of the components.

A second goal of Experiment 2 was to explore whether any associative deficit that the older adults showed would relate to their intention to learn the associative information. Information can be encoded and stored incidentally when participants do not encode it in preparation for a test, or information can be encoded intentionally when participants expect a memory test on this information. One of the questions regarding memory for associations in older adults is whether their memory for associative information is deficient under both incidental and intentional learning of the associations. Some neuropsychological models and findings support such a hypothesis. For example, Moscovitch (1992) suggested a neuropsychological model of memory that comprises several components. One of the components is the medial temporal/hippocampal, which binds events together by simple temporal contiguity into memory traces. This system works in a rather automatic fashion under incidental conditions. A second component involves the frontal lobes and is in charge of strategic information processing, including the implementation of elaborative and organizational schemes to help encode the information. This is an effortful system that requires resources.

There are indications that both systems do not function at their prime with advancing age. For example, Davies and Bernstein (1992) showed that tests considered to be mediated by the hippocampal component are influenced by age, and Craik, Morris, Morris, and Loewen (1990) showed that tests that are considered to be mediated by the frontal lobes are also affected by old age. According to Moscovitch's (1992) model and these neuropsychological findings, one may expect older adults' memory for associations to be deficient under both incidental and intentional learning instructions (see Chalfonte & Johnson, 1996, for a similar claim).

In the second experiment, I assessed the degree to which old age differentially affects memory for associative and item information. The type of association used in this experiment was the episodic relationships established between two unrelated words that appeared together (interunit associations). Word pairs were presented to the younger and older adults for study under instructions to either learn the items separately or learn the pairs for an upcoming memory test. As in Experiment 1, item memory was tested by a recognition test in which half of the items were studied (targets) and half were not (distractors). Associative memory was tested by presenting participants with target items only, either as intact pairs (items that were presented together at study) or as recombined pairs (items presented in different pairs at study), and asking them to recognize the intact pairs. In addition, study instructions were manipulated: Half of the participants expected an item memory test, and the other half expected an associative memory test. As in Experiment 1, the ADH predicted an interaction of age and test.

Experiment 2

Method

Participants. Participants were 80 younger and 80 older adults. They were taken from the same pools of participants as in Experiment 1. Their mean ages, their number of years of formal education, and the male:female proportion appear in Table 1.

Design. Three independent variables were used: age (young vs. old), study instructions (study items vs. study pairs; between subjects), and test (item vs. pairs; within subjects).

Materials. The materials were similar to those used in Experiment 1, except that word pairs were used. The study phase included presentation of 48 word pairs on index cards. The first 4 pairs served as practice. Of the next 44 pairs, 4 (2 at the beginning and 2 at the end) were used as buffers. The remaining 40 word pairs served as the experimental stimuli. Words belonging to different pairs were also unrelated to each other in any apparent way. Four random versions of word pairings were created and two random orders were used for each of these pairings to create eight versions.

Procedure. The procedure used was the same as that used in Experiment 1, with the following changes. Half of the participants (40) in each age group (study-items instructions) were told to study the words in each pair individually in preparation for an upcoming item recognition test, the nature of which was explained. The other half of the participants (40) in each age group (study-pairs instructions) were told to study the word pairs in preparation for an upcoming pair recognition test, whose nature was also explained.

Presentation rate was 1 pair every 6 s. After presentation of the first 4 pairs for practice, two short tests, a word recognition test and a pair recognition test, were given. After participants' questions were answered, the experimental phase started, in which participants were presented with the 44 experimental pairs, 1 at a time without a pause.

After an interpolated activity similar to that used in Experiment 1, the two memory tests listed below, one for items and one for their associations, were administered to all of the participants. The order of the tests was counterbalanced across all of the participants in each combination of age and study instructions, and each word or word pair appeared in only one of the tests.

1. *Item recognition test.* The test was similar to the one used in Exper-

iment 1 but with 20 targets and 20 distractors; half of the targets were the words that appeared on the right side of the index cards during the study phase, and half were words that appeared on the left side. No 2 words from the same pair were used as targets in this test.

2. *Associative recognition test.* The test was similar to the one used in Experiment 1, with 10 intact (targets) and 10 rearranged (distractors) pairs.

Results

As in Experiment 1, to obtain an overall picture of participants' performance, measures of proportion of hits minus false alarms were computed for each participant and then averaged over each age group for every condition separately.

Figure 2 presents results for proportion of hits minus proportion of false alarms in the different conditions. A 2 (age) \times 2 (study instructions) \times 2 (test) mixed factorial ANOVA was performed on this measure. There was a significant effect of age, $F(1, 156) = 33.90$, $MSE = 0.104$, where the younger participants (.49) performed better than the older participants (.28). There was also an effect of study instructions, $F(1, 156) = 5.82$, $MSE = 0.104$, where instructions to pay attention to the pairs resulted in better performance (.43) than instructions to pay attention to the items (.34). The effect of test was also significant, $F(1, 156) = 46.98$, $MSE = 0.041$, where participants' performance on the item test (.46) was better than performance on the associative test (.31). More important for the test of the ADH, the interaction of age and

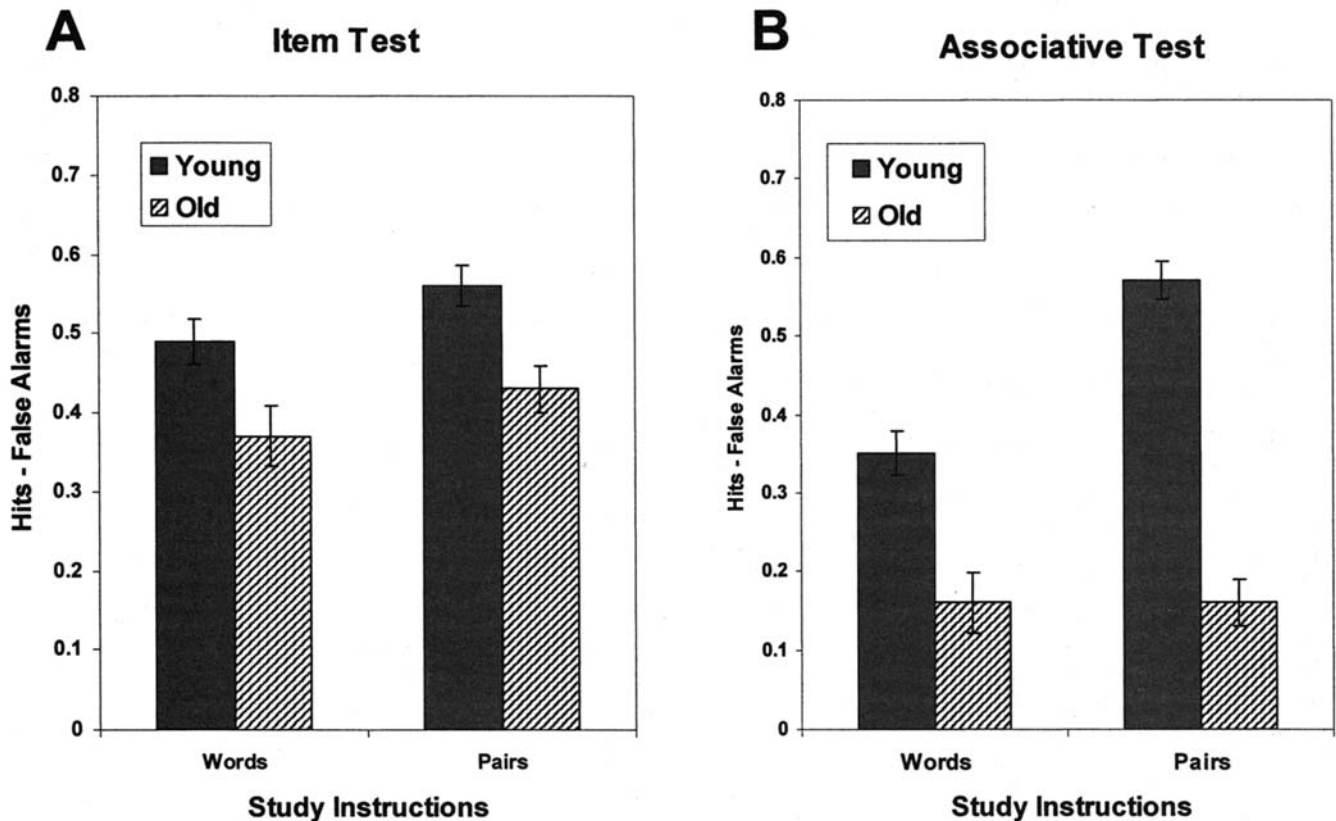


Figure 2. Proportion of hits minus proportion of false alarms (\pm SEs) in (A) the item (words) recognition test and (B) the associative (pairs) recognition test for the younger ($n = 80$) and older participants ($n = 80$) in the different study-instructions conditions of Experiment 2.

test was significant, $F(1, 156) = 10.50$, $MSE = 0.041$, indicating much poorer performance of the older participants relative to the younger participants in the associative test (.16 and .46, respectively), $F(1, 156) = 35.21$, than in the item test (.40 and .53, respectively), $F(1, 156) = 13.88$.

Finally, the triple interaction was significant, $F(1, 156) = 5.69$, $MSE = 0.041$. Further analysis indicated that the locus of this interaction was the different patterns in the relationships between age and instruction condition for each test. In the item memory test, there was no interaction between age and study instructions, $F(1, 156) = 0.18$, $MSE = 0.054$, whereas in the associative test there was a significant interaction between age and study instructions, $F(1, 156) = 6.70$, $MSE = 0.091$. The source of this interaction was the age effect, which was much larger in the associative test under instructions to study associations (intentional learning of associations; .57 for younger adults and .16 for older adults), $F(1, 156) = 36.31$, than under instructions to study items (incidental learning of associations; .35 for younger adults and .16 for older adults), $F(1, 156) = 5.60$. Under both types of instructions, however, the differences between the younger and older adults were statistically significant.

The performance of the older adults in each combination of study instructions and test was significantly better than chance (.00).

As in Experiment 1, I wanted to rule out the possibility that the observed age-related differences in associative memory were partially due to the fact that the younger and older adults were not equated on word memory and to inspect age differences in associative recognition when word recognition scores were taken into account. To this end, an ANCOVA was performed after I verified that the assumption regarding the homogeneity of the regression slopes was not violated ($p > .05$ for all t tests comparing the slopes). Age and instructions were used as the independent variables, associative recognition was used as the dependent variable, and word recognition was used as the covariate. It showed a significant effect of age, $F(1, 155) = 20.73$, $MSE = 0.07$; no significant effect of instructions, $F(1, 155) = 2.34$, $p > .10$, $MSE = 0.073$; and a significant interaction, $F(1, 155) = 7.15$, $MSE = .073$. The source of this interaction was the larger age differences under study-pairs instructions (intentional learning of associations; .50 for younger adults and .18 for older adults), $F(1, 155) = 26.13$, than under study-items instructions (incidental learning of associations; .33 for younger adults and .23 for older adults), $F(1, 155) = 2.74$. The latter effect was only marginally significant ($p < .10$). These results indicate that the older adults had a deficit in the associative recognition test that extended beyond their deficit in item recognition, especially when instructed to study pairs.

Discussion

The results of this experiment are quite clear. Most importantly, the older adults showed a differential poorer performance in recognition of associative information than in item information compared with the younger adults. Apparently, the older adults did not encode and store associative information as well as the younger adults.

In addition, the older adults showed the deficit in memory for associative information when it was encoded incidentally under

study instructions to pay attention to the single items (.35 for younger adults and .16 for older adults). Furthermore, their associative memory performance did not improve when their attention at encoding was focused on the associative information (attention to items = .16, attention to associations = .16). This was in clear contrast to the younger adults, who remembered associative information much better when instructed to pay attention to it during the study phase (attention to items = .35, attention to associations = .57).

Tests of an ADH

In Experiment 3, I contrasted different predictions made by the contextual deficit hypothesis (e.g., Burke & Light, 1981; Rabinowitz, Craik, & Ackerman, 1982) and the ADH, and in Experiment 4 I contrasted different predictions made by the self-initiation/environmental support hypothesis (e.g., Craik, 1983, 1986) and the ADH.

Experiment 3

Associations are required not only for relating single units together (interitem connections), as discussed and exemplified in Experiments 1 and 2, but also for connecting together different attributes within a unit. A dominant view in cognitive psychology (e.g., Underwood, 1969) assumes that an episode is composed of several attributes (e.g., semantic, acoustic, and contextual), which are connected together to create a coherent distinctive unit. Past research has indicated that older people are especially deficient in encoding a rich context. Light (1992), in her review of the literature, argued convincingly that older people probably do not have problems in encoding the conceptual-semantic context but have problems with the encoding of perceptual-contextual information. This claim is supported by several studies that have shown that older adults have problems in remembering the temporal-spatial contextual attributes of an event (e.g., McIntyre & Craik, 1987; Naveh-Benjamin, 1987, 1988, 1990) or other attributes (e.g., modality, font, color, or voice; Kausler & Puckett, 1980, 1981a, 1981b; Naveh-Benjamin & Craik, 1995, 1996; Park & Puglisi, 1985).

In all of the above studies, however, memory for a perceptual-contextual attribute was tested by providing participants with the original event (usually a word or a picture) and asking younger and older adults either to recall the attribute (e.g., the voice that presented this event during the study phase) or to recognize the attribute (e.g., whether this event was presented in this voice during the study phase). Testing memory for attribute information in the above manner, however, is confounded in a way that may not allow one to disentangle deficits in memory for specific attribute information from other memory deficits. This is due to the fact that when the original event (item) is presented during the test phase, either in the original voice or in a different voice, the failure of older people to identify whether this was or was not the voice that presented this word could result from three different sources. First, such a failure could be due to poorer perceptual-contextual attribute memory of older people; that is, they do not remember the voice as well as younger participants. This, in fact, was the interpretation provided for such results in all of the above studies,

which concluded that older people's memory for perceptual-contextual information is poor.

There are two other possible causes for poorer performance of older people in such a test. One is their poorer memory for conceptual-focal attributes. If participants do not recognize the word itself in the test phase, this could potentially impair their ability to remember the voice that uttered this word in the study phase. This possibility was addressed in different ways in the literature. For example, in some studies (e.g., Kausler & Puckett, 1980; Naveh-Benjamin & Craik, 1995, 1996), participants were given a separate recognition test for the words in addition to the recognition test on the perceptual-contextual attribute. Such a procedure may allow one to estimate the relative deficiency of older adults in memory for focal information (e.g., words) and to demonstrate that such a deficiency is smaller (or sometimes not present at all) than that observed in the perceptual-contextual test (see also Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994).

However, beyond a possible deficit in focal-word memory performance, there may be a third source that could underlie older adults' manifested perceptual-contextual attribute memory deficit. This source is the association between the perceptual-contextual attribute and the focal-word information. For example, a deficiency in recognition memory for the voice in the test mentioned above, where an item is presented in its original voice or a different voice, could be due to either a deficit in memory for the contextual attribute or a deficit in memory for the association between the contextual attribute and the focal-word information. This is so because the test for context, as conducted in the literature, includes both the focal information (word) and the context (voice), and older adults' failure to indicate whether a given word appeared in a specific voice could occur either because they do not remember the voice or because they do not remember that this word appeared in this voice. Researchers need to separate the contributions of a failure to remember the voice itself from a failure to remember the association between the voice and focal-word information.

If one characteristic of advancing age is, as this study claims, a failure to remember associations among unrelated episodic events/attributes, one may expect that one cause of older people's perceptual/contextual memory deficit is their problem in relating the various attributes to each other and not in remembering the attributes themselves. Their performance on a memory test for attribute information will depend on the degree to which the test requires memory regarding the associations among attributes. If a memory test can be devised that requires only information about the perceptual-contextual attributes, but not about their relationships to other attributes (e.g., focal-word-conceptual ones), one may expect little (or no) disadvantage of older people on such a test. Tests that require the association among attributes may reveal, in contrast, a significant deficit in older people.

One source of support for the deficient performance of older adults in tests requiring associations among attributes comes from a study by Chalfonte and Johnson (1996). In this study, younger and older adults were presented with colored items located within an array. Older adults showed disproportionate deficit in recognition memory for location but not for item or color. More important to this discussion, older adults also showed poorer memory for combinations of attributes, especially when these attributes were acquired intentionally.

To allow for an evaluation of differences between younger and older adults in memory for single attributes and their associations, I devised three memory tasks, each of which was supposed to test a different facet of the information. I used the form (font) in which words were presented as the perceptual-contextual attribute. Words were presented for study in 1 of 18 fonts. I compared younger and older adults' memory for the words, for the fonts in which the words were presented, and for the relationships (conjunctions) between specific words and specific fonts.

For this purpose, during the test phase, participants received (a) a pure recognition test on the words (in this test, some of the original words [targets] appeared with new words [distractors]; all of the words during the test phase appeared in a neutral font [one which had not been presented at study]), (b) a pure recognition test on the fonts (in this test, the original fonts [targets] were mixed with other new fonts [distractors] and were presented without the words [using XXXX] for a recognition test), and (c) a recognition test on the conjunctions-associations of words and fonts. In this test only original (target) words and fonts were presented. In half of the cases, the word was presented in the original font (intact events), and in the other half of the cases the word was presented in a different font than the one in which it appeared during the study phase—a font that appeared with another word during the study phase (recombined events). Such a test requires that participants have information about the relationships between the words and the fonts, and it is similar in nature to the recognition test for interitem associations used in Experiments 1 and 2.

To summarize, in Experiment 3, I compared younger and older adults' performance on memory for word information, memory for perceptual-contextual information (the font in which the words are presented), and memory for the relationships between the two. I also assessed, as in Experiment 2, the effects of the different instructions (i.e., study words, study fonts, and study words + fonts) at encoding on memory for each type of information. One third of the participants in each age group received instructions during the study phase to learn the words, one third received instructions to learn the fonts, and one third received instructions to learn the relationships (combinations) of the words and the fonts. As in the first two experiments, the ADH predicted an interaction of age and test, with age differences expected to be the largest in the word-font association test.

Method

Participants. Participants were 54 younger and 54 older adults. They were taken from the same pools of participants as in Experiment 1. Their mean ages, their number of years of formal education, and the male:female proportion appear in Table 1.

Design. Three independent variables were used: age (young vs. old), study instructions (study words, study fonts, and study words + fonts; between subjects), and test (words, fonts, and words + fonts; within subjects).

Materials. The materials were similar to those used in Experiment 1, except that 48 words were used. The study phase included presentation of 48 words on index cards, with the first 4 words serving as practice. Of the next 44 pairs, 8 (4 at the beginning and 4 at the end) were used as buffers. The remaining 36 words served as the experimental words. For the word memory test, additional 24 distractor words were chosen. The words had the same characteristics as those used in Experiments 1 and 2. Forty different computer fonts were originally generated. To be sure that the fonts were distinguishable from each other, the fonts were pretested in a

group of participants who were asked to provide pair-similarity judgments on these fonts. A multidimensional scaling was performed on these judgments, and only the 28 fonts that were the farthest apart from each other (the most dissimilar) were chosen as the experimental fonts. Eighteen of these fonts were randomly chosen and used as targets and 10 were used as distractors for the font test. For the study phase, two random versions of word–font pairings (36 words, each 2 appearing in a given font) were created and three random orders of presentations were used for each of these pairings to create six versions.

Procedure. The procedure used was the same as that used in Experiment 1 with the following changes. One third of the participants (18) in each age group (study-words instructions) were told to study the words in preparation for a word recognition test, whose nature was explained. Another third of the participants (18) in each age group (study-fonts instructions) were told to study the fonts in preparation for a font recognition test, whose nature was explained. Finally, one third of the participants (18) in each age group were told to study each word and the font in which it appeared in order to prepare for a test on the combinations of words and fonts, whose nature was explained.

Presentation rate at study was one word every 6 s. The practice phase, including the short practice tests, was the same as in Experiments 1 and 2, except that members of each study-instructions group were tested only on that aspect that they were told to attend to. This was done to make sure that participants attended during the study phase only to the feature to which they were told to. After the participants' questions were answered, the experimental phase was run as in Experiment 1 and 2 with 44 experimental items.

After an interpolated activity similar to that used in Experiments 1 and 2, the three memory tests listed below were administered to all of the participants. The order of the tests was counterbalanced across all of the participants in each combination of age and study instructions (3 participants in each combination). The number of items in each test was determined in such a way that each word, font, or word–font combination could appear in only one of the tests without repetition. This was done to avoid across-tests item reexposure effects.

1. **Word recognition test.** The test was the same as the one used in Experiments 1 and 2, except that participants saw 36 words, 1 at a time. Twelve of these were targets, and 24 were distractors, which were mixed randomly. The use of one-third proportion of targets was determined to avoid ceiling effects. All of the words appeared in a neutral font—a font that did not appear either during the study phase or during the test phase of the font recognition test. Participants were told that 12 of the 36 to-be-presented words appeared in the study phase and that they should indicate them on the response page with which they had been provided.

2. **Font recognition test.** In this test, 10 original fonts that appeared during the study phase were mixed randomly with 10 distractor fonts and presented 1 at a time. To avoid any effects of the previously presented words, all of the fonts appeared using XXXX combinations. Participants were told that 10 of the 20 to-be-presented fonts appeared during the study phase and that they should indicate which ones they were on the response sheet with which they had been provided.

3. **Word–font combination test.** In this test, 16 pairs of word–font combinations, all of which had appeared during the study phase, were presented 1 at a time. To avoid carryover effects from the font test (and vice versa), the words used were those that appeared during the study phase in one of the eight fonts not used in the font test. Likewise, the fonts used in this test did not appear in the font test. Eight of the pairs were intact from the study phase (i.e., word–font pairs that had appeared together in the study phase). The other eight pairs were rearranged ones; they were composed of words and fonts taken from different study word–font combinations. Participants were told that all of the words and fonts appeared in the study phase and were instructed to circle the 8 of the 16 to-be-presented combinations that had appeared as such (intact) during the study phase.

For all of the tests, participants had as much time as they needed to provide a response for each test item. Note that although only 28 target words were used during the test phase (12 in the word test and 16 in the

word–font combination test), 36 experimental words were presented during the study phase. This was done to equate the frequency of appearance of each font (twice) during the study phase.

Results and Discussion

As in Experiments 1 and 2, measures of proportion of hits minus false alarms were computed for each participant for each test and then averaged over each age group for each study-instructions condition separately.

Figure 3 presents results for the proportion of corrected hit measure (hits minus proportion of false alarm rates). A 2 (age) \times 3 (study instructions) \times 3 (test) mixed factorial ANOVA was performed on this measure. There was a significant effect of age, $F(1, 102) = 11.86$, $MSE = 0.053$, where the younger participants (.34) performed better than the older ones (.25). The effect of test was also significant, $F(2, 204) = 60.18$, $MSE = 0.051$, where participants' performance on the word test (.49) was significantly better than their performance on both the font test (.19) and the word–font combination test (.20), $F_s(1, 102) = 98.27$ and 117.91 , respectively. Performance on the latter two tests did not differ, $F(1, 102) = 0.08$.

There was also a significant interaction of study instructions and test, $F(4, 204) = 3.39$, $MSE = 0.051$, where performance in any given test was the best under instructions to pay attention during the study phase to the feature tested (see Figure 2). More importantly, the interaction of age and test was significant, $F(2, 204) = 11.16$, $MSE = 0.051$, indicating much poorer performance for the older participants relative to the younger participants in the word–font combination test than in the word test and the font test. Follow-up contrasts indicated significant differences between the younger (.33) and older adults (.07) in the word–font combination test, $F(1, 102) = 34.29$, but no significant differences between the younger and older adults either in the word test (for younger adults, $M = .49$; for older adults, $M = .49$), $F(1, 102) = 0.02$, or in the font test (for younger adults, $M = .20$; for older adults, $M = .19$), $F(1, 102) = 0.06$.

The performance of the older adults in each of the tests (.49 in the word test, .19 in the font test, and .07 in the word–font combination test) was significantly better than chance (.00).

In this experiment, I did not perform an ANCOVA, as was done in Experiments 1 and 2, because no differences emerged between the younger and older adults in the word and font recognition performance.

The results of this experiment are clear. The corrected hit measure indicated that the older adults showed a significantly worse performance in recognition of combinations of words and fonts (i.e., associative information) than the younger adults.⁵ This

⁵ As pointed out by one of the reviewers, the fact that I used fewer fonts than words during the study phase (18 and 36, respectively) resulted in each font being paired with 2 different words during encoding. This could have made the associative recognition test more difficult, especially for the older adults, as they might have been more prone to the effects of proactive and retroactive interference caused by this double pairing. However, I do not think that this determined the pattern observed. First, the literature on age-related interference effects is unequivocal with respect to the differential effects on younger and older adults (see Kausler, 1994, pp. 354–362, for a review). Second, there are indications in the literature (e.g., Schacter

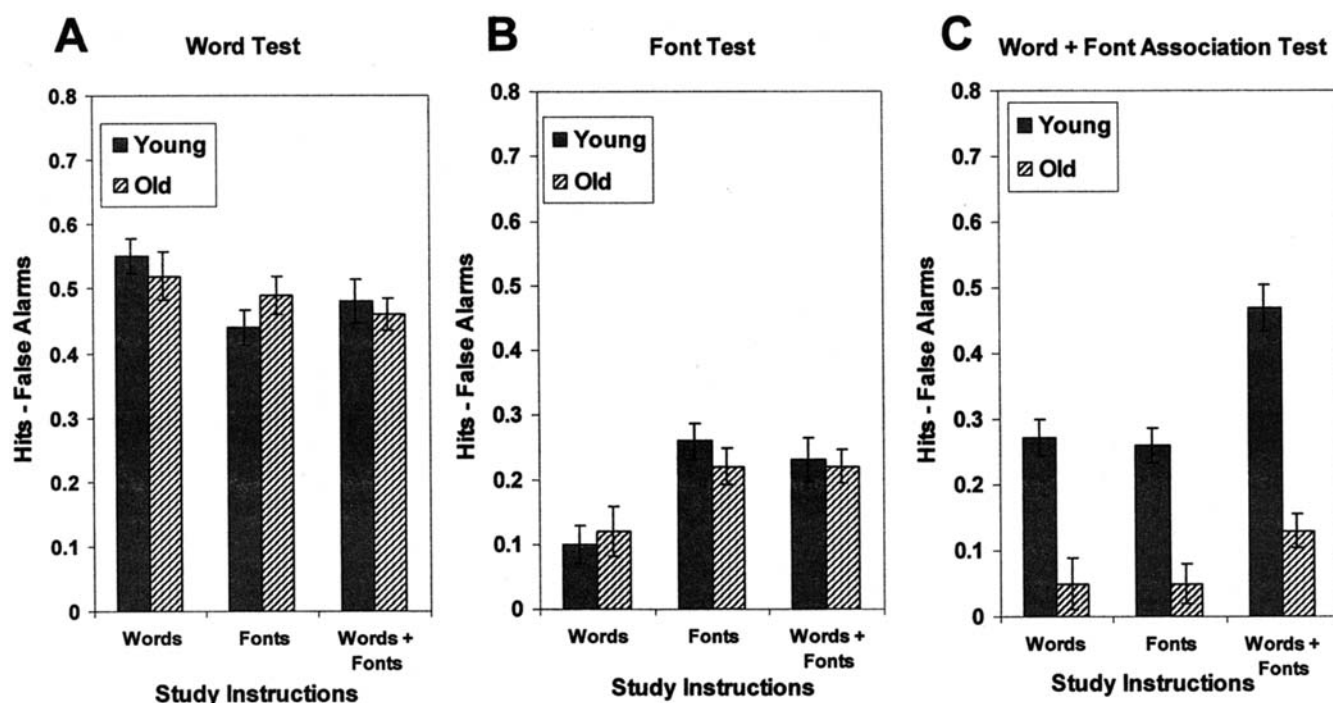


Figure 3. Proportion of hits minus proportion of false alarms (\pm SEs) in the (A) words, (B) fonts, and (C) words + fonts recognition tests for the younger ($n = 54$) and older participants ($n = 54$) in the different study-instructions conditions of Experiment 3.

is in clear contrast with their recognition memory for the words and the fonts separately, which was as good as that of the younger adults. Apparently, older people do not encode and store associative information about relationships among attributes (in this experiment, those between words and the font in which they are presented) as well as young people.

Interestingly, when the appropriate test is used for the perceptual-contextual attribute (the font test that is uncontaminated by word-font associations), older adults perform as well as younger ones.⁶ This indicates that the results of previous research, showing disproportionately large age differences in memory for perceptual-contextual attributes, might have been due, at least in part, to the inappropriate method of testing used. Using a somewhat similar paradigm, Chalfonte and Johnson (1996) showed that older adults' deficient perceptual-contextual attribute memory might depend on the specific attribute studied. In their study, older adults showed a deficit in memory for spatial location accompanied by intact memory for color.

Finally, in this experiment, as in Experiment 2, the older adults' deficit in memory for associative information (information about the relationships of words and fonts) was present under incidental learning of the associative information. This was indicated by the age effect under study-items instructions, which was significant for

the associative test (.27 for younger adults and .04 for older adults), $F(1, 102) = 19.25$, $MSE = 0.052$, but not for the item test (.35 for younger adults and .37 for older adults), $F(1, 102) = 0.02$, ns , $MSE = 0.056$. It was also present under intentional learning of the associative information (.47 for younger adults and .13 for older adults) in the associative test, $F(1, 102) = 15.40$, $MSE = 0.052$, but not in the item test (.36 for younger adults and .34 for older adults), $F(1, 102) = 0.09$, ns , $MSE = 0.056$. Overall, the older adults seemed to have been deficient both in incidental encoding of intraitem associations and in intentional learning of associative information. Such large differences under intentional instructions to learn associations have also been reported by Chalfonte and Johnson (1996); however, their results for the association of item and context are not unequivocal because of potential ceiling effects in item recognition memory. Such an effect might have masked some differences in item memory that could have also affected the performance of older adults in the associative test. Note that although the trends obtained in the present study indicated greater age-related differences in memory for associative information under intentional learning than under incidental learning of associations, the triple interaction (which was significant in

et al., 1994) that even in a one-to-one pairing of fact and source, older adults show a disproportional decline in memory for the association of fact and source. Finally, the results of this experiment were very similar to those reported in Experiments 1 and 2, where the components of each presentation were exclusively paired in a one-to-one fashion.

⁶ The adequate performance of the older adults in the font test could be due to each font being presented twice during the study phase. Previous research, however, has indicated a deficit in older adults' explicit memory even when stimuli are repeated during the study phase (Cohen, Sandler, & Schroeder, 1987). Furthermore, the lack of age differences in word recognition strengthens the claim that some attribute information, unlike associative information, is unaffected by old age.

Experiment 2) did not approach statistical significance in Experiment 3.

Overall, these results, indicating a differential deficit of older adults in a task requiring the association of contextual elements together, but not in tasks requiring memory for each of the contextual elements separately, can be explained more parsimoniously by an age-related ADH than by an age-related contextual deficit hypothesis.

Experiment 4

There is a fairly large body of knowledge indicating that age-related difficulty in retrieval is a major reason for poorer memory performance in older adults. One might expect recognition performance, where the information is re-presented during the test phase (and hence could help induce the appropriate mental operations necessary for retrieval), not to be affected by age as much as recall performance, where participants must create the mental operations necessary for successful retrieval. This prediction is generally supported: For example, Schonfield and Robertson (1966) reported much larger age-related decrements in recall than in recognition memory tasks. Similarly, Rabinowitz (1984, 1986) and Craik and McDowd (1987) found that recall performance was more affected by age than recognition performance.

This pattern of results has been explained by Craik (1983, 1986) in terms of a trade-off between internal mental processes and environmental support. Craik (1983, 1986) argued that the activity of remembering should be seen as an interaction between external information (from stimuli and their context) and internal mental processes (well-learned schematic information plus self-initiated processing). If older adults use self-initiated processing less effectively, they should show a disadvantage when such processing dominates a task (e.g., free recall) but should perform relatively well in cases where the environment supports the retrieval (e.g., recognition tasks). Self-initiated processing may be particularly demanding when there are reduced processing resources, as is the case with older adults. In such a case, a good environmental support could be one way to achieve good performance when processing resources are reduced.

Such a position predicts that differences between younger and older adults' memory performance will decrease as the amount of environmental support increases. The continuum of memory tasks, which provides different amounts of environmental support and requires different amounts of self-initiated activity, goes from free recall (where no cues are presented) to cued recall (where partial cues are presented) to recognition (where a copy of the stimulus serves as a cue). According to the environmental support/self-initiated processing framework (Craik, 1983, 1986), one would expect large age differences in free recall, smaller ones in cued recall, and still smaller ones in recognition. The ADH tested here provided different predictions, however. A cued-recall task that involved the direct encoding and retrieval of specific associations among items was predicted to be the most age sensitive because older participants encounter problems in creating and retrieving associations between unrelated pairs of items. Free recall, which also involves, at least indirectly, creating relationships between items (Mandler, 1979), was predicted to be somewhat less age sensitive, as it involves other operations not directly related to the retrieval of specific associations (e.g., an initiation of a memory

search and generation of cues; Atkinson & Shiffrin, 1968). Finally, item recognition, which is the least dependent on associative information, was predicted to be the least age sensitive. A major difference between the environmental support/self-initiated processing hypothesis and the ADH is in their differential predictions regarding age sensitivity for free recall and cued recall: Whereas the former predicts reduced age sensitivity to cued recall, the latter predicts the opposite. In Experiment 4, I tested these contrasting predictions.

To increase the specificity of the ADH predictions, I contrasted the above predicted pattern, which is relevant when unrelated pairs are used and when temporal-spatial episodic relationships have to be created, with a situation in which the creation and retrieval of these associations can be supported by preexisting semantic associations (e.g., when semantically related pairs are used). In the latter case, where much less episodic distinctiveness is necessary, and previous knowledge can support the creation of associations, one would expect much smaller differences, if any, between younger and older adults. In particular, older adults should benefit the most when semantically related pairs are used in the cued-recall task because the use of preexisting associations will be the most beneficial in the task that relies the most heavily on the encoding and retrieval of associative information.

To summarize, in the following experiment, I compared younger and older adults' memory performance in three tasks: free recall, cued recall, and recognition. Unrelated pairs were studied in one condition, and semantically related pairs were studied in the other.⁷ Participants received three lists of word pairs in a counter-balanced order, and after each list they performed one of the three memory tasks. Learning was intentional, and the nature of the tests was known in advance.

Method

Participants. Participants were 36 younger and 36 older adults, who were taken from the same pools as those run in Experiments 1-3. Their mean ages, their number of years of formal education, and the male:female proportion appear in Table 1.

⁷ One further feature to note in Experiment 4 is the use of paired associates at the encoding stage of all three memory tasks. Customarily, researchers use lists of single items in free-recall and recognition tasks but pairs of words in the cued-recall task. For the present experiment, there may be two problems with such a procedure. First, if one wants to evaluate performance in both related and unrelated pairs, for purpose of comparison one has to use both related and unrelated pairs during the study phase for all of the tasks. More importantly, if pairs of words are used in the cued-recall task, and single words in the free-recall and recognition tasks, then, if the pattern predicted by the ADH is observed (namely, the relatively poorest performance of older adults in the cued recall of unrelated-pairs task), a counterargument can be made claiming that such a pattern is merely a manifestation of the simple case of the age complexity effect. If participants have to encode pairs of items in the cued-recall task, and only single items in the free-recall and recognition tasks, then the deficits of older adults in the cued-recall task relative to other tasks could be at least partially explained by the differential complexity of the encoding required in cued recall (pairs) versus that required in free recall or recognition (single words). To rule out this possibility, pairs of words were encoded in each task.

Design. Three independent variables were used: age (young vs. old), type of pairs (related vs. unrelated semantically; between subjects), and task (free recall, cued recall, and recognition; within subjects).

Materials. The study phase for each of the tasks included the presentation of 16 pairs of words on index cards. Of the 16 pairs, 4 (2 at the beginning and 2 at the end) were used as buffers. The remaining 12 pairs served as the experimental stimuli. For the word recognition test, 24 additional distractor words were chosen. All of the words were high-frequency two- and three-syllable Hebrew nouns taken from Balgur (1968). The two words in each pair of the unrelated condition were unrelated semantically to each other. The two words in each pair in the related condition were semantically related using Hebrew norms (Henik & Kaplan, 1988). In both conditions, there were no semantic relationships between words of different pairs or between words in the different lists. For the study phase, three lists with the above characteristics, one for each task, were created and completely counterbalanced across the different tasks. Two random orders of presentation during the study phase were used for each of these lists.

Procedure. Participants who were tested in groups of 1 to 2 saw three lists of word pairs, one for each task. Half of the participants in each age group received the unrelated pairs, and the other half received the related pairs. For each task, the list of 16 pairs was presented sequentially during the study phase at a rate of one item every 5 s for the younger participants and one item every 10 s for the older participants (see Rabinowitz et al., 1982, for a similar procedure). This differential presentation rate was deemed necessary after pilot testing indicated a floor effect for older adults when a 5-s pace was used, accompanied by a ceiling effect for younger adults when a 10-s pace was used (see below for further discussion of this issue).

All of the lists were run under intentional learning instructions. In all of the lists, participants were told to try to learn the pairs but to pay special attention to the second word in each pair (the target word). They were also told to pay attention to the first cue word because it could help them memorize and retrieve the target word. Participants were told before the beginning of the experimental phase about the three possible memory tasks to be performed, although they were not told in advance which list each was associated with or that each of the memory tasks would necessarily be used during the experiment. This ensured an identical study phase in all of the tasks in terms of participants' expectations. Responses to questionnaires administered after the experiment indicated no differences between the younger and older adults in the anticipation of the specific upcoming tests.

For the free-recall task, participants were told that during the test phase they would have to memorize and write down as many of the targets as possible. For the cued-recall task, participants were told that during the test phase the first cue word of each pair would be provided and their task was to come up with its paired word. For the recognition task, they were told that during the test phase they would be given the 12 targets plus 24 distractors and that their task would be to circle the 12 targets out of the 36 candidate words. Participants were not told in advance whether the pairs were related or unrelated but could have noticed that during the practice phase.

Before the beginning of the experimental phase, participants received three short practice lists accompanied by a short version of one of the tests after each list. At the end of practice, participants' questions were answered before the experimental phase started.

For each task, participants were presented with the 16 experimental pairs (including 2 primacy and 2 recency buffer pairs), 1 at a time without a pause. After the end of the study phase, participants had to count backward by threes for 60 s as an interpolated activity. Then the three memory tasks listed below were administered to all of the participants, one for each list. The order of the tasks across the three lists was counterbalanced across all of the participants in each combination of age and type of pairs (3 participants in each combination).

1. **Free recall task.** In this task, participants were asked to write down on the response sheet as many of the target words (the second word in each pair) as possible.

2. **Cued-recall task.** In this task, participants saw each of the cue words in each pair (presented in a random order) and were instructed to write down on the response sheet the target word that appeared with each cue in the study phase.

3. **Recognition task.** In this task, participants saw 36 words, 1 at a time. Twelve of these were the targets from the study phase, and 24 were distractors, which were mixed randomly. The distractors were 24 words of the same characteristics as the target words but did not appear in the study phase. Participants were told that 12 of the 36 to-be-presented words had appeared in the study phase as targets and that they should indicate them on a numbered page that was in front of them.

For all of the tests, participants had as much time as they needed to provide a response for each test item.

Results

To compare directly performance on the three memory tasks, I used the proportion correct of free-recalled targets for the free-recall test, the proportion correct of targets in the cued-recall test, and the proportion of hits minus the proportion of false alarms for the recognition test (see Craik & McDowd, 1987, for a similar procedure). Because there were only a few false alarms in the free-recall and cued-recall tasks (except for one condition, the semantically related pairs in free recall, which is discussed separately), this equated the three tasks in terms of the chance level (0.0). These measures were computed for each participant and then averaged over each age group for each pair-type condition separately.

Figure 4 presents the means for the above measures for the younger and older participants in the different pair-type conditions. A 2 (age) \times 2 (pair type) \times 3 (memory task) mixed factorial ANOVA was performed on the memory scores. The effect of age was significant, $F(1, 68) = 25.11$, $MSE = 0.033$, where the younger adults (.54) performed better than the older adults (.43). The effect of type of pairs was also significant, $F(1, 68) = 44.88$, $MSE = 0.033$, where performance for related pairs (.57) was better than for unrelated pairs (.39). Finally, the effect of memory task was also significant, $F(2, 136) = 198.17$, $MSE = 0.024$. Follow-up contrasts showed that performance in the recognition test (.73) was significantly better than performance in the cued-recall test (.44), $F(1, 68) = 100.23$, which, in turn, was significantly better than performance in the free-recall test (.28), $F(1, 68) = 58.80$.

More related to the present hypotheses, the interaction of age and memory task was significant, $F(2, 136) = 3.92$, $MSE = 0.024$. As can be seen in Figure 4, the differences between the younger and older adults were the largest in the cued-recall test (.18), smaller in the free-recall test (.10), and the smallest in the recognition test (.04). The interaction of age and pair type was also significant, $F(1, 68) = 9.19$, $MSE = 0.033$. Follow-up contrasts showed that the source of this interaction was the significant age effect in unrelated pairs (for younger adults, $M = .49$; for older adults, $M = .29$), $F(1, 34) = 38.73$. There were no significant differences between the younger ($M = .58$) and older adults ($M = .56$) in memory performance for related pairs, $F(1, 34) = 0.42$.

Although the triple interaction only approached significance, $F(2, 136) = 2.59$, $p < .08$, $MSE = 0.024$, follow-up interaction comparisons (Keppel, 1982), testing the specific hypothesis dis-

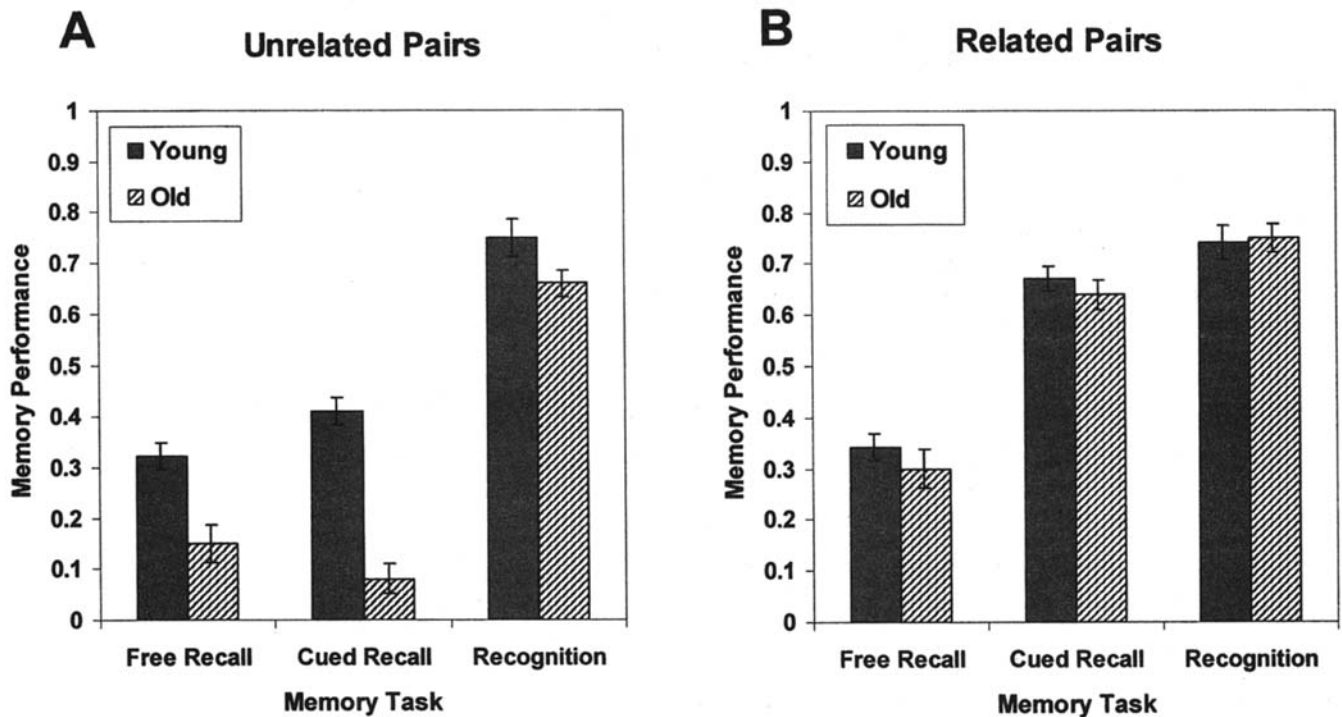


Figure 4. Proportion of hit rates in the free-recall and cued-recall tests and proportion of hits minus false alarm rates in the recognition test (\pm SEs) for the younger ($n = 36$) and older participants ($n = 36$) in the (A) unrelated- and (B) related-pairs conditions of Experiment 4.

tinguishing the environmental support/self-initiated processing position from that of the ADH, indicated that the interaction of age and memory task was statistically significant for the unrelated pairs, $F(2, 68) = 4.36$, $MSE = 0.026$, but not for the related pairs, $F(2, 68) = 1.72$, $MSE = 0.022$. Follow-up contrasts of the unrelated-pairs condition indicated that whereas the differences between the younger and older participants were significant for each of the three tasks, the difference between the younger and older participants for cued recall (.33) was significantly larger than that for either free recall (.17) or for recognition (.10), $F_s(1, 34) = 4.78$ and 5.19 , respectively.

Because a major difference between the environmental support/self-initiated processing hypothesis and the ADH is their differential predictions regarding age sensitivity in free-recall and cued-recall tasks for unrelated pairs, I performed an ANCOVA where the younger and older participants were compared on the cued-recall test for unrelated pairs, using free-recall performance for unrelated pairs as the covariate. The ANCOVA was performed after I verified that the assumption regarding the homogeneity of the regression slopes was not violated ($p > .05$ for the t test comparing the slopes relating the cued-recall performance to the free-recall performance in the younger and older adults for unrelated pairs). The analysis yielded adjusted mean cued recall scores of 0.33 and 0.15 for the younger and older participants, respectively. These differences were statistically significant, $F(1, 33) = 3.64$, $MSE = 0.16$; thus, the performance of the older group was relatively worse on the cued-recall test than on the free-recall test.

Finally, as mentioned above, false alarm rates in the free- and cued-recall tasks were very low for both age groups. The only condition in which rates were relatively high was in the free recall of semantically related pairs, where the rates were significantly higher for the older adults (1.80 words) than for the younger adults (0.70 words). A significant portion of this difference must be attributed to the tendency of the older adults to free recall cues rather than targets, more so than the younger adults. This was probably due to the semantic relatedness between cues and targets and the relative inability of the older adults to distinguish between the two.

Performance of the older adults in all of the conditions, except for the unrelated pairs in the cued-recall task, was significantly better than chance (.00).

Discussion

The results of Experiment 4 indicate that the older adults showed a disadvantage in memory for unrelated pairs. In particular, the largest difference between the younger and older adults was obtained in the cued recall of unrelated pairs. Such a pattern is consistent with an ADH, which claims that the cued-recall task of unrelated pairs (which involves the direct encoding and retrieval of associations), will be the most age sensitive, even more so than free recall. When the cued-recall task, however, demands less reliance on the creation of new associations and a greater use of previously learned associations (the semantically related-pairs condition), the differences between the younger and older adults

disappeared altogether. Such a pattern is less consistent with the environmental support/self-initiated processing hypothesis, which predicts, as discussed earlier, smaller age differences with the addition of external cues (i.e., in the cued-recall task relative to the free-recall task).⁸

Note that there were no differences in any of the memory tasks in the performance of the younger and older adults when related pairs were used. Apparently, when semantic memory is heavily involved in a given task, older adults can take an advantage of it to match the performance of younger adults (see also Light, 1992).

One methodological issue should be addressed. As mentioned earlier, to raise the older adults' performance, I used slower presentation rates during the study phase for this group. This apparently did not affect the patterns of performance for the younger and older adults, although it might have affected the overall age effect. Table 3 presents the data for 8 younger and 8 older participants in a pilot study that was run precisely as the one reported above, except that the same presentation rate (5 s per item) was used for the younger and older adults. As can be seen, although the performance of the older adults was poorer than their performance as described in Figure 4 (which was obtained using a 10-s presentation rate), the patterns obtained, especially for unrelated pairs, were very similar to the ones reported above. Particularly, the largest age differences are seen in the cued-recall task for unrelated words. The pattern for related pairs was also similar to the above-reported results, although there were, overall, larger age differences. This indicates that the lack of any overall age-related differences obtained for related pairs in Experiment 4 should be treated cautiously and could have been masked by the differential presentation rates.

General Discussion

The results of the four experiments are consistent with the hypothesis tested in this study, which attributes at least part of older adults' deficient explicit episodic memory performance to their decreased ability to encode and retrieve associations among units of information or attributes within events. Experiments 1 and 2 dealt with memory for item and interitem associations, and their results indicate that when memory for item and for associative relationships among items are compared directly, older adults show a disproportionately larger deficit in the latter. Note that when item information is difficult to encode (among other things, due to

the need to create episodic associations in order to encode it appropriately; e.g., nonwords in Experiment 1), older adults show an appreciable deficit in its memorization.

Experiment 3 dealt with memory for intraitem associations. Younger and older adults' memory for an event's attributes, and their relationships (associations) with each other, was compared. Results indicated that the memory performance of the older adults for single attributes (words and fonts) was as good as that of the younger adults but that their memory for the conjunctures of attributes was deficient. Somewhat similar results with different attributes were reported by Chalfonte and Johnson (1996). As mentioned earlier, however, in their experiments item memory performance was at ceiling. As a result, the differences between older and younger adults in item-context associations could be due at least in part to older adults' deficient item memory. Using words and background pairs, Denny, Miller, Dew, and Levay (1991) showed small age differences in memory for word-background pairs that were of the same magnitude as that for memory for words and backgrounds separately. Their test of word-background conjunctures, however, was equivocal because it used, in addition to intact and recombined pairs, new words and new backgrounds as well, the combination of which can be rejected on the basis of either item or associative information. This

⁸ Two alternative explanations can be raised to explain the poorer performance of the older adults in the cued-recall test. One concerns different response criteria used by the younger and older adults in the different tests: Although in the cued-recall test there is one "right" answer for each item, in the free-recall test there is not. As a result, if the older adults are less likely to provide responses when they are not sure, they might show a greater deficit in cued recall than in free recall. Two reasons make this possibility unlikely. First, if that were the case, it should have resulted in the poorer performance of the older adults on the tests of cued recall for both the related and unrelated pairs. The fact that there were no differences between the younger and older adults in the cued-recall task with related pairs (where performance was much below ceiling) is inconsistent with an explanation based on the use of different response criteria by the older adults. Furthermore, analysis of the number of errors made in the free-recall and cued-recall tasks indicated a slightly higher level of errors for the older adults in both tasks and for both types of pairs. These included intralist errors in the cued-recall task (providing a wrong response with another list item) and extralist errors (providing a wrong response with an item that was not part of the list) for both the cued- and free-recall tasks. If the older participants had used a more stringent criterion for response in the cued-recall task, one would have expected them to make fewer errors.

Another alternative explanation of the results of this experiment concerns the possibility that in the free-recall task participants can capitalize on any associations that they create among the items, whereas in the cued-recall task they must discover relations among arbitrarily paired particular items. Older adults may have more difficulty with the latter. Such an explanation is unlikely given the results obtained and the procedure used. First, the results indicated no differences between the younger and older adults in the cued recall of related pairs, despite the somewhat arbitrary nature of the specific pairs used (even in the case of related pairs, participants would have had ample opportunity to choose a semantically related B to a Cue A). Second, and more importantly, as noted in the *Method* section, pairs of items were presented in all of the memory tasks at encoding, without the participants' knowledge of the specific test to be given. Hence, older, as well as younger, adults had to process both the items and their association in the free- and cued-recall tasks.

Table 3
Proportion of Hit Rates in the Free-Recall and Cued-Recall Tests and Hit Minus False Alarm Rates in the Recognition Test for the Younger and Older Participants in the Related- and Unrelated-Pairs Conditions (Experiment 4, Pilot Study)

Age and type of pairs	Test		
	Free recall	Cued recall	Recognition
Young			
Unrelated	.33	.45	.77
Related	.38	.65	.78
Old			
Unrelated	.08	.00	.62
Related	.15	.50	.70

renders problematic any conclusions regarding memory for associations.

Experiments 2 and 3 demonstrated the same patterns of performance (although different in magnitude) by indicating that older adults may have a twofold deficit. First, they are deficient in the incidental ("automatic") encoding of associative information when they are not paying attention to it (which was significant in Experiment 3 and marginally significant in the ANCOVA for Experiment 2). Second, when their attention is directed to the associative information (intentional encoding), they exhibit an even larger deficit (which was significant in Experiment 2 but not in Experiment 3) in using "strategic behavior" to help them encode such information. These deficient "automatic" and "strategic" encoding processes are in line with the aforementioned neuropsychological model and the empirical evidence for changes in brain structures (Moscovitch, 1992). Apparently, older adults seem to have deficits both in the hippocampal/limbic system, which is supposed to automatically bind together information for storage, and in frontal lobe areas, which are used to process information strategically.

In Experiment 4, the younger and older adults' memory for semantically related and unrelated pairs was compared and tested using three different memory tasks: free recall, cued recall, and recognition. The older adults showed disproportionately poorer performance in a cued-recall task of unrelated pairs—a task that particularly requires the use of episodic associative information—relative to their disadvantage in free-recall and recognition tasks. When the older adults did not have to create new associations (e.g., when the pairs to be remembered were semantically related), they performed as well as the younger adults in the cued-recall task. Using the three memory tasks with unrelated pairs under instructions to image items separately or interactively, F.I.M. Craik (personal communication, July 1997) obtained somewhat similar results, where the largest differences between younger and older adults were in the cued-recall task.

In each of these experiments, memory for associative information was compared with memory for other types of information shown to be not deficient, or less so, in old age. In Experiments 1 and 2, memory for item information was much less affected by age; in Experiment 3, memory for words and for perceptual-contextual attribute (font) was not affected by old age; and in Experiment 4, performance under free-recall or recognition tasks was less affected by old age. Furthermore, the results of the ANCOVAs, where the younger and older adults' memory for associative information was compared while item information differences (if any) were controlled statistically, converged to show the same patterns, where the older adults exhibited a deficit in memory for associative information.

Note that in Experiments 1–3, the tasks used the recognition procedure, which puts less heavy demand on retrieval processes and hence reflects more encoding (and storage) processes. In Experiment 4, at least part of the older adults' deficit in cued recall for unrelated pairs could be attributed to retrieval processes, although retrieval deficit alone could probably not explain the overall pattern. Older people perform relatively better in a free-recall task, when the most unconstrained retrieval activity is required, than in a cued-recall task. Because the four experiments showed a differential associative deficit in older adults, which was affected by manipulations both at encoding (instructions) and at retrieval

(test types), the most parsimonious conclusion is that older adults' deficient memory for associations is due to problems both at encoding and in explicit retrieval.

Altogether, the results of Experiments 1–3 demonstrate the potential role that a deficit in the processing of relationships—associations between single units (an episode's components) may play in older adults' memory performance. The components can be either two separate units (e.g., words) or more integrated ones (a word and its context). Although I did not test memory for the relationships among contextual attributes of a given episode, I expect the same patterns of performance, whereby older adults would exhibit a disproportionate deficit in memory for the relationships among the attributes relative to their memory for the attributes themselves.

The results of Experiments 3 and 4 also provide the ADH with a discriminant validity by contrasting and testing competing predictions made by this hypothesis and those based on alternative ones. These results support predictions made by the ADH over those made by the contextual deficit (Experiment 3) and the self-initiated/environmental support hypotheses (Experiment 4).

The present results cannot be interpreted as a simple case of the age complexity effect (Clay, 1954; Salthouse, 1988). The claim could be made that the associative tests are in principle more complex and involve more mental operations than those involved in item tests. There are two indications that the age complexity effect cannot account for the present results. First, results by Hockley (1991, 1992) show that associative information is forgotten by younger adults at a slower rate than item information. If associative information is characterized only by its complexity, one would have expected the more complex associative information to be forgotten faster. Second, the results of Experiment 4, which indicate relatively poorer performance of older adults in cued recall of unrelated words than in free recall, are not in line with the age complexity explanation; free recall involves as many mental operations as cued recall and is no less complex.

The results obtained here, indicating an age-related deficit in the encoding of associative information, do not contradict those obtained using implicit memory procedures. Results of the associative priming procedure (e.g., Fleischman & Gabrieli, 1998; Howard, Fry, & Brunc, 1991; Howard, Heisey, & Shaw, 1986; Light, Kennison, Prull, La Voie, & Zellig, 1996; Light, La Voie, Valencia-Laver, Albertson Owens, & Mead, 1992; Light, La Voie, & Kennison, 1995; Moscovitch, Winocur, & McLachlan, 1986) are not definitive with respect to the question of the existence of age-related differences in associative priming. Older adults seem to be deficient in associative priming when elaborative encoding is required to produce it (Howard et al., 1991). Similarly, the results based on methodology of implicit effects of memory for context on item recognition (e.g., Naveh-Benjamin & Craik, 1995), which may indicate good implicit encoding of associations between words and modality or voice in older and younger adults, are obtained only when participants use a shallow level of processing during the study phase but not when elaborative processing instructions are used.

So far, the results in the literature regarding the deficiency of older adults in the implicit encoding of new associations are inconclusive with a plausible interpretation in terms of a deficiency of older adults when elaborative processes are used. Such a conclusion is not contrary to the results obtained in the experi-

ments presented in this article, which indicate a larger deficit for older adults in the encoding and retrieval of associative information under instructions to learn this information intentionally. Presumably, under such conditions more elaborative encoding strategies can be used, resulting in a superior performance of younger adults in the explicit memory task.

Although the ADH focuses on the encoding and retrieval of associations, it is related, at least in part, to other hypotheses advanced to explain life-span development in episodic memory performance. Its relationship to the contextual deficit hypothesis was discussed in Experiment 3 and to the self-initiation/environmental support view in Experiment 4. Note that because the intention of this study was to make a case for associative deficit being one important component in age-related losses rather than an all-embracing exclusive factor, other hypotheses advanced clearly have a role in episodic memory losses in old age. As an example, several researchers (see Burke & Light, 1981, for a review) have suggested that one reason for the poor episodic memory of older adults is their deficiency in using adequate encoding strategies (e.g., the production-deficiency hypothesis; Kausler, 1970). Although several lines of research do not support this as a general hypothesis (see Light, 1991, for a review), the results reported in this article are in line with a narrower version of such a hypothesis. According to this version, older adults have a particular problem in using strategies to create new associations. Two aspects of the results reported in this article are in line with such a suggestion. First, in both Experiments 1 and 2, older adults' deficient memory for new associations was especially evident when participants were specifically instructed to learn the associations, implying that older adults, in contrast to younger ones, do not use appropriate strategies under such conditions. Second, postexperimental questionnaires used in Experiment 2 indicated that older adults, more so than younger adults, tended not to use any strategy to relate the word pairs but instead tended to encode the words individually. When the older adults did report using a strategy, it tended to be a low-level one (e.g., rehearsal of the word pair). In contrast, younger adults reported more extensive use of integrative strategies (e.g., creating a sentence to connect the word pairs).

Finally, a couple of general comments on the ADH tested in this article should be made. Although the ADH suggests a reduced ability of older adults to encode and retrieve associations, it is not committed to the exact microlevel mechanisms responsible for such deficits. These mechanisms might be related to a reduction in priming transmitted across connections among units due to declined linkage strength (MacKay & Burke, 1990), a decreased efficiency of the simultaneity mechanism (Salthouse, 1996), or an inefficient binding mechanism (Chalfonte & Johnson, 1996). I believe that any such microlevel mechanism would have to account for an inefficient mechanism to create new associations, as well as for the decreased efficiency in the retrieval of such associations.

Another related issue addresses the specification of the nature of the associative process. There might be several ways in which an association can be formed. One is as a blended (mixture) representation, where the components (words or features) are still represented independently. The other is as a compounded representation, where the new representation is a compound of the previous one and is qualitatively different from the two components separately. The latter is characterized by a new gestalt-type

representation, where information about the association is more than just the sum of its components (see Chalfonte & Johnson, 1996, and Clark & Gronlund, 1996, for a related distinction). Future research could address the question of whether younger and older adults might have qualitatively different types of associative information. Older adults, who seem to possess a more fragmented episodic representation, may have more blended (mixture) types of associations, whereas younger adults, who possess more cohesive episodic representations, may have more compounded types of associations.

To summarize, an associative hypothesis that explains and predicts older adults' deficient explicit episodic memory performance was tested. This hypothesis suggests that a significant cause of older adults' deficient memory performance is their difficulty in merging different aspects of an episode into a cohesive unit. In a sense, the glue that links together the various aspects (attributes) of an episode is not as efficient in old age. As a result, although each of the components may be retained to a reasonable degree, the associations that tie the attributes-units to each other grow weaker in old age.

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