

Adult Age Differences in Episodic Memory: Further Support for an Associative-Deficit Hypothesis

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This study further tested an associative-deficit hypothesis (ADH; M. Naveh-Benjamin, 2000), which attributes a substantial part of older adults' deficient episodic memory performance to their difficulty in merging unrelated attributes—units of an episode into a cohesive unit. First, the results of 2 experiments replicate those observed by M. Naveh-Benjamin (2000) showing that older adults are particularly deficient in memory tests requiring associations. Second, the results extend the type of stimuli (pictures) under which older adults show this associative deficit. Third, the results support an ADH in that older adults show less of an associative deficit when the components of the episodes used are already connected in memory, thereby facilitating their encoding and retrieval. Finally, a group of younger adults who encoded the information under divided-attention conditions did not show this associative deficit.

Memory researchers interested in lifespan development have attempted to explain adult age differences in memory performance with the aim of both increasing 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 the old, including (a) a deficit in semantic processing, (b) a failure of metamemory, (c) a failure of deliberate recollection, (d) a reduction in processing resources (see Light, 1991, for a review) and in processing speed (Salthouse, 1996), and (e) a failure of inhibitory processes (Hasher & Zacks, 1988). Although all of the above relate to older adults' memory deficits, especially those deficits that characterize episodic memory, none of them provides an explanation for the full range of phenomena associated with older adults' episodic-memory deficit.

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; MacKay & Burke, 1990). Recently, Naveh-Benjamin (2000) has suggested an associative-deficit hypothesis (ADH) that focuses on the distinction between memory for single units and memory for association among units. Naveh-Benjamin (2000) hypothesized that a major factor in 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 old people's memory performance.

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, (a) the relationships of two messages were treated within a paired-associates paradigm, (b) the relationships of a message and a voice were treated as memory for context, and (c) the memory for a message in a specific time and place was investigated as memory for source. All of these examples, however, involve the establishment of connections among single units at one level or another.

There have been several suggestions in the literature that support a separation within memory of information about single units from information about associative relationships among these units (e.g., J. R. 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).

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The research literature on memory and aging concentrates on memory for items and memory for relationships among items. However, most of this research treats each type of memory individually. When these types of memory are compared directly, it is almost never as a way of specifying differential mechanisms, but it is in a context of a comparative task performance, with item memory serving mostly in recognition paradigms and associative memory serving in paired-associate and free-recall paradigms.

As suggested by Naveh-Benjamin (2000), if we want to directly compare memory for item and associative information, we need 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, one must choose tasks that minimize retrieval effects. One procedure that applied this method is the one used by Humphreys (1976). 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 the A item is taken from one pair and the B item from a different pair. Participants have to recognize which of the pairs appeared in its present form, originally. Participants in such a procedure encode the same information at study, and at test they are provided with all of the information in both tests, and hence the differences in performance between the two tests reflect differential memory for item and associative information (see the General Discussion section).

Although this procedure has been used in the literature on young adults (e.g., Glenberg & Bradley, 1979; Humphreys, 1976; Naveh-Benjamin & Jonides, 1984) 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; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Naveh-Benjamin, 2000). As mentioned previously, the studies with young participants established different patterns of performance for item and associative information.

Naveh-Benjamin (2000) has tested an ADH in a series of studies, using the previously described procedure. This was done by first demonstrating an associative deficit in two experiments, each of which used different tasks that require the processing of both single units and their interconnections and second, by contrasting, in two further experiments, predictions made on the basis of an ADH with those made on the bases of other current hypotheses. Specifically, the results of the four experiments reported by Naveh-Benjamin (2000) were consistent with an ADH. Experiments 1 and 2 in Naveh-Benjamin's (2000) study dealt with memory for item and interitem associations, and the results indicated that when memory for item and for associative relationships among items are compared directly, older adults show a disproportionately greater deficit in the latter. The components of the episodes were either words and nonwords (Experiment 1) or words (Experiment 2).

Experiment 3 of Naveh-Benjamin (2000) dealt with memory for intraitem associations. Younger and older adults' memory for an

event's attributes and their relationships (associations) with each other were compared. Results indicated that the memory performance of older adults for single attributes (words and fonts) was as good as that of 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). In addition, Experiments 2 and 3 of Naveh-Benjamin (2000) demonstrated the same patterns of performance by indicating that the deficit of older adults may be twofold: First, they have a deficit in the incidental ("automatic") encoding of associative information when they are not paying attention to this information. Second, when their attention is directed to the associative information (*intentional encoding*), they exhibit a deficit in using "strategic behavior" to help them encode such information.

In Experiment 4 of Naveh-Benjamin (2000) young 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. 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 older adults did not have to create new associations, for example, when the pairs to be remembered were semantically related, they performed as well as younger adults in the cued-recall task.

The studies reported in this article were intended to extend the empirical support for an ADH. First, we wanted to evaluate the degree to which the associative deficit occurs when different types of materials are used. In particular, whereas Naveh-Benjamin (2000) used only verbal stimuli, in Experiment 1 we used pictorial information where pairs of pictures were presented at study and participants' memory for each picture and their associations to each other were later tested. There are indications in the literature (e.g., Park, Puglisi, & Smith, 1986) that older adults retain pictorial information as well as younger adults, and we wanted to assess whether in this case they nevertheless show an associative deficit.

Second, we wanted to test the prediction of an ADH that the less the task requires the creation of episodic associations between the components, the smaller the associative deficit will be. To test this prediction, in Experiment 2 we presented younger and older adults with pairs of words, either unrelated or related semantically, and later tested them with item- and associative-recognition tests. We predicted that older adults would show relatively less of a deficit in the associative-recognition test when related pairs are used, allowing them to rely more on preexisting associations and less on establishing new associations. Although Naveh-Benjamin (2000) has provided support for this prediction (Experiment 4), the comparison of cued recall versus free recall was not the best possible, as cued recall, in addition to requiring associations, might also require other processes (e.g., the retrieval of the B item in an A-B pair). Therefore, some of the deficit shown by Naveh-Benjamin (2000) may be related to differences in item availability. As mentioned previously, the use of the associative-recognition test (in addition to the item-recognition test) in which all of the target items are present at test, makes it especially suitable for the assessment of memory for associations.

Third, we wanted to relate the work on the ADH to a suggestion made in the literature regarding the underlying cause of older adults' episodic-memory decline. Craik and his collaborators (e.g., Craik, 1983, 1986; Craik & Byrd, 1982) suggested that an age-

related reduction in attentional or processing resources may underlie the older person's episodic-memory deficiency. Moreover, they associated these age-related changes with those occurring in younger adults who are operating under conditions of reduced attentional capacity (e.g., divided attention [DA]). The suggestion is that effortful cognitive operations, such as elaboration at encoding and reconstructive operations at retrieval, require substantial attentional resources and that elderly people have fewer of these resources. According to this suggestion, younger adults under DA conditions presumably invest some of their limited attentional resources in performing the secondary task; operating with reduced attentional resources devoted to the memory task, they would therefore show patterns of memory performance similar to older adults. Several studies in the literature support this assertion (e.g., Craik & McDowd, 1987; Rabinowitz, Craik, & Ackerman, 1982). To test whether reduction in attentional resources may be a mediating factor in the age-related associative deficit, in each of the two experiments reported below we have also tested a group of younger adults under the conditions of DA and compared their performance with that of the older adults. If the associative deficit of older adults is mediated by a decline in attentional resources, then we would expect younger adults under DA to show the same associative deficits as predicted for older adults.

Experiment 1

The purpose of this experiment was to extend the range of materials used in the test of an ADH beyond that of words. To do so, we presented participants with a list of different events where each event comprised a pair of pictures. There are some indications (e.g., Park, et al., 1986; Rybarczyk, Hart, & Harkins, 1987; Till, Bartlett, & Doyle, 1982) that there are only slight age-related differences in the recognition of pictures. It has been suggested that pictures provide for a more distinct and coherent representation of information; if true, this might allow older adults to create a cohesive representation of the event enabling them to overcome their associative deficit. In addition, we compared the effects of DA in young adults and those of age on memory for the components of the events and for their association with each other. To do so, we used three groups of participants: young adults under full attention (FA), young adults under DA at encoding, and older adults under FA. According to an ADH for older adults (Naveh-Benjamin, 2000), we would expect older adults to show a differentially poorer memory on tests of the associations among the pictures. If this hypothesis is also relevant to DA at encoding, we would expect young participants under such conditions to perform differentially worse on tests for the memory of the associations between the components than on the components themselves.

Method

Participants. Participants were 36 younger and 18 older adults. The younger participants were undergraduate students at Ben-Gurion University who participated in the experiment as part of their course requirements. The older participants were residents of Beer-Sheva, Israel, who lived independently in the community. The mean age and education level for each group in each of the experiments reported in this article appear in Table 1. In this experiment, as well as in Experiment 2, there were no differences between the younger and the older adults in level of formal education. All of the older adults in this experiment reported being in good health and having good hearing and vision.

Table 1
Means and Standard Deviations for Age and Number of Years of Formal Education in Experiments 1 and 2

Group	Young FA	Young DA	Old
Experiment 1			
Age			
<i>M</i>	24.3	22.8	76.2
<i>SD</i>	3.7	2.2	6.1
Education			
<i>M</i>	12.9	13.0	13.2
<i>SD</i>	1.7	0.4	3.6
Experiment 2			
Age			
<i>M</i>	21.4	22.6	73.7
<i>SD</i>	2.5	3.4	6.3
Education			
<i>M</i>	12.8	12.6	13.9
<i>SD</i>	0.8	1.0	3.2

Note. FA = full attention; DA = divided attention.

Design. We used a Group (young FA, young DA, older adults) \times Test (items vs. associations) design manipulated between subjects and within subjects, respectively.

Materials. The materials included 28 pictures of simple objects. We paired these randomly to create picture pairs in which pair members were not related visually, semantically, or auditorily. The study phase included the visual presentation of the picture pairs. We used four pairs (two at the beginning and two at the end) as buffers. The remaining 24 pairs served as the experimental stimuli. We created two versions of the picture pairs and used two random orders for each of these pairings for a total of four versions. Four or 5 participants in each of the three groups were run in each version.

Procedure. The experimenter told participants to study the picture pairs in preparation for upcoming item- and associative-recognition tests, the nature of which he explained. Each participant was exposed to the list of picture pairs in the study phase under either the FA or DA condition, depending on his or her group assignment. The experimenter instructed participants in the FA condition to learn each pair in order to prepare for tests on the information presented. Participants in the DA condition received the same instructions and, in addition, the experimenter told them to perform the concurrent digit-detection task as accurately as possible. He told them to pay equal attention to both tasks. The secondary task involved audiotaped series of single digits ranging from 1 to 9 delivered at a pace of one every 1 s. The participants' task was to monitor the digits for target strings, defined as three successive odd digits (e.g., 571, 395) and to indicate orally whenever a target string appeared (see Craik, 1982).

Presentation rate was one pair every 4 s for the young and one pair every 6 s for the old (see Canestrari, 1963, for a similar procedure). After the experimenter read the instructions and answered any questions the participants had, the experimental phase started in which participants in each of the groups were presented with the 28 experimental pairs, one at a time without pause. After an interpolated activity of 60 s, we administered to all participants the two memory tests listed below (item recognition and associative recognition). The order of the tests was counterbalanced across all participants in each group, and each picture appeared in only one of the tests.

1. **Item recognition test:** The test included eight target single pictures presented at the study phase and eight distractors that included pictures not presented at the study phase. No two pictures from the same pair were used as targets in this test. We asked participants to indicate target pictures that had appeared in the study phase.

2. Associative recognition test: The test included eight intact (target) picture pairs belonging to the same pair at study and eight rearranged picture pairs belonging to different pairs at study. The rearranged pairs were chosen to be equally plausible to the intact ones. We asked participants to indicate the intact pairs. All test items were presented one at a time.

Results

Memory performance. The separate measures of proportion of hits and proportion of false alarms averaged over each group for each of the tests can be seen in Table 2. To assess differences between the different conditions, we computed an A' discrimination measure based on the hit and false-alarm rate (Pollack & Norman, 1964) for each participant in each condition. This equated the item- and the associative-recognition tests with respect to the scale used. In addition, the two tests were of comparable discriminating power, as indicated by the similar variability of performance in the two allowing their direct comparison as two levels of the test variable (for Experiments 1 and 2). Finally, because a preliminary analysis of variance (ANOVA) yielded no interaction effect of order of the administration of the tests with any of the independent variables, in the reported analyses for Experiments 1 and 2, performance was collapsed across the different orders. Figure 1 presents results for A' in the different conditions. We used an alpha level of .05 to interpret all of the statistical comparisons.

To specifically address the hypothesis tested in this experiment, we computed three separate 2 (group) \times 2 (test) ANOVAs on the A' . First, to test an ADHD for older adults, we performed a 2 \times 2 (young FA and old) \times Test ANOVA. The results indicated a significant effect of group, $F(1, 34) = 18.80$, $MSE = 0.022$, where the young FA group (.94) performed better than the old group (.79). The effect of test was also significant, $F(1, 34) = 34.40$, $MSE = 0.0065$, with performance on the item test (.92) being better than on the associative test (.81). More important, the interaction of the two variables was significant, $F(1, 34) = 17.66$, $MSE = 0.0065$. This reflects the fact that older adults were disproportionately impaired on the association test (.69) relative to the item test (.89) compared with younger adults (.93 and .95 for associative and item tests, respectively).

Second, to determine whether young adults under DA conditions demonstrate the same associative deficit as older adults, we

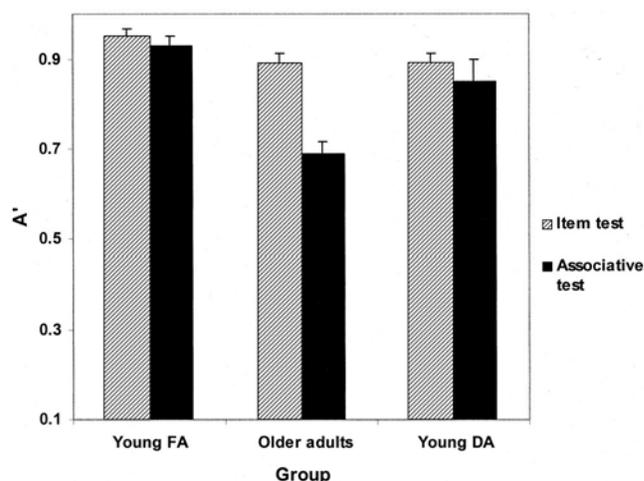


Figure 1. A' discrimination measures in the item- and the associative-recognition tests in Experiment 1. Bars depict standard errors. Young FA = young full attention; Young DA = young divided attention.

conducted a second analysis comparing young participants under FA and DA conditions using a 2 \times 2, Group (young FA and young DA) \times Test ANOVA. The results indicated a significant effect of attention, $F(1, 34) = 12.14$, $MSE = 0.0078$, where the young-FA group (.94) performed better than the young-DA group (.87). The effect of test was also significant, $F(1, 34) = 6.77$, $MSE = 0.0045$, with performance on the item test (.93) being better than on the associative test (.88). More important for an ADHD, the interaction of the two variables was not significant, $F(1, 34) = 0.36$, $MSE = 0.0045$, reflecting an equal decline in performance from the FA to the DA conditions in the item and associative tests.

Finally, when performance of young adults under DA conditions was compared with that of older adults on the two tests, the 2 \times 2 ANOVA yielded a marginally significant effect of group, $F(1, 34) = 4.03$, $MSE = 0.0270$, $p < .06$, where the young-DA group (.87) performed better than the older adults group (.79), and of test, $F(1, 34) = 25.20$, $MSE = 0.010$. Interestingly, the effect of the interaction was also significant, $F(1, 34) = 8.51$, $MSE = 0.010$. This interaction reflects the fact that older adults performed much more poorly on the associative test than on the item test (.69 and .89, respectively), relative to younger adults under DA (.85 and .89 for associative and item recognition, respectively).

The same patterns were found when age effects (the differences between the means of the younger and older adult groups in a given condition or test) were computed.¹ Performance in each combination of group and test was significantly better than chance level ($p = .5$). In addition, the performance of those in the

Table 2
Means and Standard Deviations for Proportion of Hits and False-Alarm Rates for Experiment 1

Test and group	Hits		False alarms	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Item				
Young FA	.93	.11	.02	.04
Older adults	.75	.27	.06	.13
Young DA	.79	.13	.06	.12
Associative				
Young FA	.93	.07	.13	.14
Older adults	.73	.22	.40	.22
Young DA	.86	.13	.26	.22

Note. FA = full attention; DA = divided attention.

¹ Means of the age effect in memory performance (the difference between means of the A' and d' of the younger and older adult groups in a given condition or test) were as follows: Experiment 1 (A') item-recognition test (0.06), associative-recognition test (0.24); Experiment 2 (d') item-recognition test (0.56 and 0.89, unrelated and related pairs, respectively); associative-recognition test (1.44 and 0.60, unrelated and related pairs, respectively).

young-FA condition in the item-recognition test was significantly lower than 1.00.

One reservation regarding the above reported results is that there are quite sizable age differences on at least some of the components that enter into the associations. In particular, the fact that young and old adults were not equated on item memory could have contributed to the larger age-related differences in associative information. To rule out this possibility, we performed an analysis of covariance (ANCOVA) that 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, we performed an ANCOVA to inspect age differences in associative recognition when item-recognition scores were taken as the covariate. Such a method was used by Craik and McDowd (1987) and Naveh-Benjamin (2000) to establish differential effects of age on different memory tasks.²

To use ANCOVA, we checked whether there were any violations of the assumption regarding the homogeneity of the regression slopes. To do so, we calculated (using A' measure) the regression slope for each age group relating the covariate (item recognition) to the dependent measure (associative recognition). The resulting slopes were compared with each other using a t test that showed no significant differences ($p > .05$), indicating no violation of the assumption. Therefore, an ANCOVA was performed, with age as the independent variable and item recognition as the covariate. The analysis yielded adjusted mean associative-recognition scores of 0.90 and 0.76 for the young FA and old participants, respectively. These age differences were statistically significant, $F(1, 33) = 10.78$, $MSE = 0.013$, indicating that older adults have a deficit in the associative-recognition test above and beyond that in the item-recognition test.

We used a similar ANCOVA procedure in the comparison of the young-FA and young-DA groups. The resulting adjusted mean associative-recognition scores were 0.91 and 0.86 for the FA and DA groups, respectively. These differences were not statistically significant, $F(1, 33) = 4.04$, $MSE = 0.007$, $p > .05$, indicating that younger adults under DA did not show a deficit in the associative-recognition test relative to the FA participants above and beyond that in the item-recognition test. Finally, the same ANCOVA procedure used in the comparison of the older adults with the DA group produced adjusted mean associative-recognition scores of 0.84 and 0.70 for the DA and older participants, respectively. These differences were statistically significant, $F(1, 33) = 8.48$, $MSE = 0.021$, indicating that older adults have a deficit in the associative-recognition test relative to the DA participants above and beyond that in the item-recognition test.

Secondary-task performance. Younger participants averaged 97.4% correct responses in the secondary task when performed alone and 83.3% correct responses when performed concurrently with the encoding of the pictures. This difference was statistically significant, $t(34) = 4.41$.³

Discussion

The analysis of memory performance indicated several patterns. Most important, 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 younger adults. Such results are consistent with an ADH and

extend it to cover pictorial as well as verbal materials. DA at encoding in younger adults, however, does not appear to affect differentially younger adults' memory for item and associative memory. It seems that DA, unlike age, does not differentially disrupt the storage of item and associative information. Overall, these results support an ADH as one factor in older adults' deficits in episodic memory but not as a factor underlying the effects of DA in the young.

Experiment 2

In Experiment 2 we wanted to test the prediction of an ADH that the less a task requires the creation of episodic associations between the components, the less pronounced older adults' associative deficits will be. To test this prediction, we presented younger and older adults with pairs of words, either unrelated or related semantically, and later tested them using item- and associative-recognition tests. We predicted that older adults would show less of a deficit in the associative-recognition test when related pairs are used, allowing participants to rely more on preexisting associations and less on the establishment of new ones. As mentioned previously, the use of the associative-recognition test, compared with the cued-recall test previously used by Naveh-Benjamin (2000), is especially suitable for assessing memory for associations. As in Experiment 1, we also added a group of younger participants who studied the information under DA conditions. For this group, the question was whether they would show a smaller associative deficit for the related pairs, as was hypothesized for the older adults.

In addition, we used a forced-choice item-recognition test. In each of the experiments comparing performance on item and associative recognition in the Naveh-Benjamin (2000) study, each test item in the item-recognition test (in a yes–no format) included only one item (word), whereas each test item for the associative-recognition test included two items (word pairs, intact or recombined). Although we have indications from other studies (e.g., Naveh-Benjamin, 2002) that the associative-recognition task does not require more attentional effort than the item test, here we equated the amount of information presented per test item in each of the tests. We did this by using a forced-choice item-recognition format in which each test item included two words (a target and a distractor) and in which we asked participants to identify the word that had appeared in the study phase. Such a procedure equalized the amount of information presented in each test item in the item- and associative-recognition tests.

Method

Participants. There were 90 participants, of which 60 were younger and 30 were older adults. The 60 younger adults were randomly assigned

² Note that the present use of ANCOVA differs from more traditional treatments of this procedure that 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 assure that the assumptions underlying the use of ANCOVA were met, as described in the text.

³ Because of a procedural oversight, we recorded secondary-task performance only in the dual-task condition. To assess secondary-task costs, we tested another group of 18 participants on the secondary-task-only condition. The reported t test compares the performance of the two groups.

Table 3
Means and Standard Deviations for Proportion of Hits and False Alarm Rates for Experiment 2

Test and condition	Unrelated				Related			
	Hits		False alarms		Hits		False alarms	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Item								
Young FA	.86	.15	.21	.16	.87	.15	.19	.20
Older adults	.77	.17	.25	.18	.75	.15	.26	.18
Young DA	.69	.16	.26	.15	.75	.14	.33	.15
Associative								
Young FA	.70	.20	.16	.13	.86	.12	.19	.13
Older adults	.44	.19	.33	.22	.83	.15	.35	.23
Young DA	.59	.16	.29	.19	.68	.14	.43	.14

Note. FA = full attention; DA = divided attention.

to either the FA ($n = 30$) or the DA ($n = 30$) conditions. Participants in the younger age group were undergraduate students at either the University of Toronto or the Ben-Gurion University who took part in the experiment for course credit. The older age group consisted of paid participants recruited from the Toronto and the Beer-Sheva communities. Their mean age and number of years of formal education appear in Table 1. All participants had normal vision and hearing and reported being in a good state of health.

Design. We used a Group (young FA, young DA, and older adults) \times Test (items vs. associations) \times Relatedness (related vs. unrelated pairs) design manipulated between subjects (group) and within subjects (test, relatedness).

Materials. Study stimuli were two lists of 60 word pairs consisting of 30 related pairs and 30 unrelated pairs in each list.⁴ The words were high-frequency common nouns taken from the Connecticut Free Association (CFA) norms (Bousfield, Cohen, Whitmarsh, & Kincaid, 1961). The 30 related pairs for each list were created by pairing six words belonging to a given semantic category. Ten semantic categories were used (e.g., clothing). The 30 unrelated word pairs for each list were created by combining words from across categories. These pairs were renormed to assess the strength of their relatedness. This was done by asking a group of 10 people to rate on a scale ranging from 1 (*unrelated*) to 10 (*closely related*) how related they thought the two words in each pair were. Pairs with a mean relatedness rating higher than 7.5 were chosen for the related condition, and pairs with a mean rating of less than 4 were chosen for the unrelated condition. For the test phase, the stimuli for the item-recognition test were 24 old items and 24 new distractors. The related and unrelated old items were respectively chosen from related and unrelated pairs in the study list. The distractors in the related and unrelated conditions for a given target were words with respectively high- and low-frequency association rankings to the target word in the CFA norms. For the associative-recognition tests, the word lists for each test consisted of 24 intact pairs (12 related and 12 unrelated) and 24 recombined pairs (12 related and 12 unrelated). The 24 intact related and unrelated pairs were the identical word pairs we showed in the original list. We created 12 related recombined pairs by recombining words across pairs from within the same semantic category in the list. We created 12 unrelated pairs by randomly recombining words across pairs from unrelated pairs in the list.

Procedure. For each list, participants saw 60 word pairs one at a time on a computer screen at a rate of 5 s per pair. Study conditions were intentional, and we told participants that they must pay attention not only to each item but also to the associations between pairs because their memory for both items and associations would be tested. Participants in the DA condition performed a secondary task during the study phase of each of the two lists. This was a continuous auditory choice-reaction-time (CRT) task, in which participants heard one of three possible tones: a low-frequency tone (500 Hz), a medium-frequency tone (1000 Hz), or a

high-frequency tone (1500 Hz) at a rate of one tone every 1.5 s. Their task was to press the key on the keyboard that corresponded to the tone they heard. We monitored performance for both accuracy and speed. We obtained baseline performance on the secondary task by having each participant perform the secondary task alone for 2 min after the completion of each of the two study-test phases. There were two types of tests for each word list:

1. Item recognition test: The test included 24 original targets, each paired with either a related or a nonrelated distractor (depending on whether the target word was in a related or nonrelated pair at study) that did not appear in the study phase. We asked participants to indicate which of the items had appeared in the study phase for each test pair.

2. Associative recognition test: The test included 24 intact pairs (12 related and 12 unrelated), belonging to the same pair at study, and 24 recombined pairs (12 related and 12 unrelated), belonging to different pairs at study. The 12 recombined related pairs were taken from related pairs at study, and the 12 recombined unrelated pairs were taken from unrelated pairs at study. We asked participants to indicate the intact pairs.

For both item- and associative-recognition tests, each test item was presented on the screen, and the participant responded by pressing a key. The order of list presentation was counterbalanced across all participants.

Prior to the study session, all participants received a practice session in which they were shown a list of 12 word pairs in the same manner as at study, and then performed the associative and the item tests. In addition to practice for the word pair's study phase and test phase, the young participants in the DA condition also practiced the CRT task for a 2-min duration. They also received practice with the DA task during the study phase. The study phase began only after we ensured that all participants thoroughly understood the tasks required of them.

Results

Memory performance. As in Experiment 1, we computed measures of the proportion of hits and false alarms in the associative-recognition test and the proportion correct in the item-recognition test for each participant and then averaged over each group for each of the tests. These measures can be seen in Table 3. To assess

⁴ The use of different numbers of stimuli during the learning phase in each of the experiments and different numbers of test items between experiments were a result of pilot studies; the actual number of stimuli for each experiment was determined to avoid ceiling effects in the young and floor effects in the old and to create scales of similar sensitivity for younger and older adults for each experiment.

differences between the different conditions, we computed a d' discrimination measure based on the hit and false-alarm rates (see Macmillan & Creelman, 1991) for each participant in each condition.⁵ This equated the item- and the associative-recognition tests with respect to the scale used. Figure 2 (A and B) presents results for d' in the different conditions. Three separate 2 (group) \times 2 (test) \times 2 (relatedness) ANOVAs were computed on the d' 's, each comparing two of the groups. We used an alpha level of .05 to interpret all of the statistical comparisons.

The first ANOVA comparing younger adults in the FA condition with the older adults revealed a significant effect of age, $F(1, 58) = 14.28$, $MSE = 3.21$, indicating that the overall memory performance of younger adults (2.20) was better than that of older adults (1.34). There was also a significant effect of test type, $F(1,$

58) = 14.18, $MSE = 0.88$, where performance on the item test (1.98) was better than on the associative test (1.56). There was a significant effect of target relatedness, $F(1, 58) = 12.78$, $MSE = 0.88$, where performance was better on the related (1.98) than on the unrelated (1.55) pairs.

Support for an ADH was evinced in the significant triple interaction effect found among age, pair relatedness, and test type, $F(1, 58) = 6.29$, $MSE = 0.80$. Follow-up interaction comparisons indicated that whereas for young adults the interaction between test type and pair relatedness was not significant, $F(1, 58) = 0.78$, $MSE = 0.80$, it was significant for older adults, $F(1, 58) = 19.67$, $MSE = 0.80$. The source of this interaction was the significant effect of test for unrelated pairs, $F(1, 58) = 30.07$, $MSE = 0.81$, where memory performance of older adults was disproportionately impaired on the associative test (0.42) relative to the item test (1.70). In contrast, for related pairs, older adults did not show such a deficit in the associative test (1.69) versus in the item test (1.52), $F(1, 58) = 0.66$, $MSE = 0.70$.

Results from the three-way ANOVA computed to compare the performance of younger adults in the FA and DA conditions showed a different pattern. There was a significant effect of attention, $F(1, 58) = 33.16$, $MSE = 2.51$, where overall performance was poorer in the DA condition (1.03) than in the FA condition (2.20). Thus, the DA manipulation proved successful. The effect of test was also significant where performance in the item test (1.81) was better than in the associative test (1.42), $F(1, 58) = 13.69$, $MSE = 0.66$. Neither the interaction between test type and attention condition nor the triple interaction were significant, $F(1, 58) = 1.32$, $MSE = 0.66$, and $F(1, 58) = 1.03$, $MSE = 0.58$, respectively, reflecting the fact that younger adults under DA conditions show the same performance disruption in the item test as in the associative test for both unrelated and related pairs (see Figure 2). Finally, the interaction between attention and target relatedness approached significance, $F(1, 58) = 3.97$, $MSE = 0.58$, $p = .05$, reflecting the fact that the performance advantage on related over unrelated pairs was apparent only in the FA participants (2.36 and 2.05 for related and unrelated, respectively) but not in the DA ones (0.99 and 1.07 for related and unrelated, respectively).

The final three-way ANOVA compared the performance of older adults with younger adults in the DA condition. There was no significant effect of group, $F(1, 58) = 2.32$, $MSE = 2.38$, $p > .10$, where older adults (1.34) performed similarly to the younger DA adults (1.03). There was a significant effect of test type, $F(1, 58) = 36.74$, $MSE = 0.45$, where overall performance on the item test (1.45) was better than on the associative test (0.92). The effect of relatedness was significant, $F(1, 58) = 5.34$, $MSE = 0.63$, where overall performance on related targets (1.30) was better than on unrelated targets (1.07).

The triple interaction among group, test, and pair relatedness was significant, $F(1, 58) = 13.17$, $MSE = 0.69$. Follow-up interaction comparisons indicated that the interaction between test type and pair relatedness was not significant for the younger DA adults, $F(1, 58) = 0.12$, $MSE = 0.69$, but that it was significant for older adults, $F(1, 58) = 22.81$, $MSE = 0.69$. The source of this interaction was the significant effect of test for unrelated pairs, $F(1,$

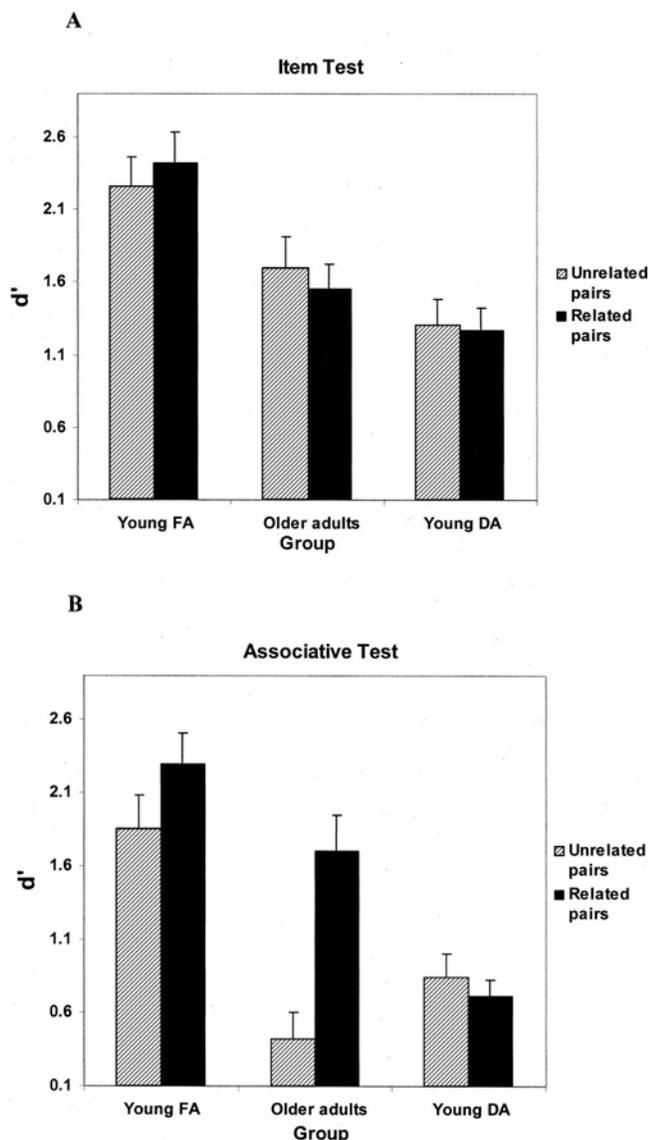


Figure 2. d' discrimination measures in the item-recognition test (A) and the associative-recognition test (B) in the relatedness conditions of Experiment 2. Bars depict standard errors. Young FA = young full attention; Young DA = young divided attention.

⁵ We have used d' rather than A' as the discrimination measure in Experiment 2 because the item-recognition test was a forced-choice one.

58) = 41.80, $MSE = 0.58$, where memory performance of older adults was disproportionately impaired on the associative test (0.42) relative to the item test (1.70). In contrast, for related pairs, memory performance of the older adults was not disproportionately impaired on the associative test (1.69) relative to the item test (1.52), $F(1, 58) = 0.81$, $MSE = 0.56$.

As in Experiment 1, we wanted to rule out the possibility that the observed age-related differences in associative memory were partially due to the fact that young and old adults were not equated on word memory and to inspect age differences in associative recognition when item-recognition scores are taken into account. To this end, an ANCOVA was performed on the d' scores after we 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 pair relatedness were used as the independent variables, associative recognition as the dependent variable, and item recognition as the covariate. The analysis yielded adjusted mean associative-recognition scores of 1.85 and 1.28 for the young FA and old participants, respectively. These age differences were statistically significant, $F(1, 57) = 7.37$, $MSE = 1.14$. There was also a significant effect of pair relatedness, $F(1, 57) = 18.14$, $MSE = 1.25$. Finally, the interaction of age and pair relatedness was significant, $F(1, 57) = 4.18$, $MSE = 1.25$, reflecting the fact that whereas younger adults did not benefit significantly from related rather than unrelated pairs, $F(1, 57) = 2.33$, $MSE = 1.25$, $p > .10$, older adults did, $F(1, 57) = 19.75$, $MSE = 1.25$. These results indicate that older adults have a deficit in the associative-recognition test that extends beyond their deficit in item recognition. This deficit, however, is modulated by the relatedness of the word pairs.

A similar procedure was used in the comparison of the young FA and DA adults. ANCOVA results yielded adjusted mean associative-recognition scores of 1.80 and 1.05 for the young FA and DA participants, respectively. These differences were significant, $F(1, 57) = 13.64$, $MSE = 0.93$. The effects of pair relatedness and its interaction with group were not significant, $F(1, 57) = 1.03$, $MSE = 0.75$, $p > .05$, and $F(1, 57) = 3.42$, $MSE = 0.68$, $p > .05$.

Finally, the same procedure was used in the comparison of the older adults and the young-DA group. ANCOVA results yielded adjusted mean scores of 0.88 for the young-DA group and 0.95 for the older adults group and showed no differences between the two groups, $F(1, 57) = 0.24$, $MSE = 0.72$, a significant effect of pair relatedness, $F(1, 57) = 10.95$, $MSE = 0.86$, and a significant interaction, $F(1, 57) = 16.88$, $MSE = 0.86$. The source of this interaction was the differences between the relatedness conditions that were significant in the older adults group, $F(1, 57) = 27.29$, $MSE = 0.86$, but not in the DA one, $F(1, 57) = 0.31$, $MSE = 0.86$. These results indicate that when unrelated pairs are used, older adults have a deficit in the associative-recognition test relative to the DA participants beyond what would be expected from their performance in the item-recognition test.

Secondary-task performance. Response times were calculated for the young-DA adults' performance on the continuous auditory CRT task. A t test on response time showed that participants' responses were faster in the baseline condition (771 ms) than in the DA condition (1,019 ms), $t(29) = 6.48$. These results validate the secondary task used here in showing that the encoding of information about the pairs presented required attentional resources diverted from the secondary task.

Discussion

The trends obtained in memory performance were consistent with the predictions made by an ADH. Rather than a generalized decrement in memory across all manipulations, older adults showed specific deficits that were attenuated in certain conditions. In particular, they showed a disproportionate impairment relative to younger adults in performance on the associative tests compared with performance on item tests, when unrelated pairs were used, which replicated prior findings that older adults clearly have deficits in binding discrete units of information together (Chalfonte & Johnson, 1996; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Naveh-Benjamin, 2000, 2002). Second, this deficit was mediated by the semantic relatedness of the units, in which inherent semantic structure in related word pairs lent cohesion to associative memory—cohesion that was absent when the word pairs were unrelated. Interestingly, these findings cannot be attributed to reduced attentional resources as might be expected by the age-related depletion of resources hypothesis; younger adults in the DA condition showed a proportionate decline in memory across all conditions and did not evince the same patterns of memory performance as older adults for either unrelated or related pairs.

Finally, note that the results of this experiment, showing an associative deficit in older adults, were obtained when a forced-choice item-recognition test was used. Such a result indicates that older adults' associative deficit is not related to the type of item test used, either a forced-choice or a yes–no one. The performance costs imposed both on the primary task (as evinced by poorer memory) and the secondary one (longer response times) confirmed that attention was effectively divided between the two.

General Discussion

The studies reported in this article were intended to extend the empirical support for an ADH. The results of Experiment 1 indicate that the deficit older adults demonstrate in the encoding and retrieval of associative information is not limited to verbal material. When pictorial information is used, older adults show a disproportionate deficit in an associative- relative to an item-recognition test. The results of Experiment 2 show that older adults demonstrate less of an associative deficit when pairs of semantically related rather than unrelated words are used. This result is consistent with an ADH in showing that when related pairs are used, allowing the older adults to rely more on preexisting associations and less on establishing new associations, their associative deficit is reduced. In each of these experiments, memory for associative information was compared with memory for the components of the episode, the performance on which was shown to be less affected by age.⁶ In addition, the same patterns of performance seem to emerge regardless of whether a forced-choice or a yes–no item-recognition test is used.

In the two experiments reported in this article we have also

⁶ In Experiment 2, the associative deficit of older adults was shown both in their lower hit rate and their higher false-alarm rate in the associative recognition test relative to younger adults. In Experiment 1, this deficit was evident only in higher false-alarm rate. Future research will determine which of these two patterns is more common.

tested a group of younger adults under DA at encoding and compared their performance with that of the younger and the older adults. Both experiments show that DA conditions substantially affected memory performance but that these effects were the same for item and associative information. In contrast to the effects of age, DA seems to similarly disrupt the encoding and retrieval of both the episode's components and their association to each other. Such different patterns for older adults and younger adults under DA conditions do not depend on the overall level of performance in the two groups and were obtained in cases where overall memory performance was better in the DA group (Experiment 1) or equal in the two groups (Experiment 2). These results do not support the suggestion that the associative deficit of older adults stems from a special reliance of the associative information on attentional resources. Such a suggestion also is not supported by recent demonstrations that retrieval of associative information does not involve more attentional resources than those required in the retrieval of component information (Naveh-Benjamin, Guez, & Marom (in press); see below for a further discussion of this issue).

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 several indications that the age-complexity effect cannot account for the present results. First, as noted by Naveh-Benjamin (2000), results by Hockley (1991, 1992) showed that associative information is forgotten by young adults at a slower rate than item information. If associative information is characterized only by its complexity, we would have expected the more complex associative information to be forgotten faster. Second, elsewhere Naveh-Benjamin et al., (in press) have assessed whether item and associative-recognition tests differ in terms of their demand for attentional resources by using a secondary task methodology at retrieval. The results, which showed secondary-task costs to be similar for item- and associative-recognition tests, point out that these two tests require the same amount of attentional resources for their execution. Finally, results reported by Naveh-Benjamin (2000, 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.

Overall, the present results extend and further support the utility of an ADH as an explanation for age-related differences in episodic-memory performance. In the following section, we discuss the possibility that a reduced attentional-resources mechanism can account for the obtained results, taking into consideration the results reported here on young people under DA. Finally, we discuss several issues that a more comprehensive ADH should address in the future.

ADH and Attention

One aspect of the present work relates to the suggestion that older adults' poorer associative memory is a result of their depleted attentional resources, then younger adults under DA at encoding should show the same associative deficit as older adults (e.g., Craik, 1983, 1986; Craik & Byrd, 1982). Although it has

been suggested that reduced attentional resources might be a common mechanism underlying the effects of age and DA on episodic memory (e.g., Craik & Byrd, 1982; Rabinowitz et al., 1982), the present results place certain constraints on such an explanation. Although both age and DA in young are associated with poorer episodic-memory performance, the locus of their effects seems to be somewhat different. Whereas aging seems to especially disrupt the associative mechanism, reduced attention at encoding in younger adults does not and is instead related to a general decrease in memory performance. One possibility is that to be as disruptive as age, attention may have to be withdrawn both at encoding and at retrieval, instead of just at encoding, as we did in the present experiments. There are several reasons, however, to suspect that this was not why DA did not have a differentially larger effect on associative mechanisms. First, DA at retrieval in young adults has little or no effect on memory performance, especially when recognition tasks are involved, as was the case in the experiments reported by Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Guez, & Dori, 1998; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000; and N. D. Anderson, Craik, & Naveh-Benjamin, 1998. Second, Craik et al. (1996) and Naveh-Benjamin et al. (in press) used both item and associative tasks and have shown no further decrease in memory performance in younger adults when attention is divided at both encoding and retrieval compared with a case of DA at encoding only.

A possible explanation for the conflict between the sets of results on the effects of DA in young and age-related changes that support the common cause hypothesis (e.g., Craik, 1983, 1986) and those reported here and in Naveh-Benjamin (2000) is that age-related changes in memory performance have multiple causes. One important cause is related to depleted attentional resources, which leads information to be encoded less distinctively and more schematically, resulting in poorer memory for item information. Such a mechanism may be operating both in older adults and in the younger adults under DA at encoding. The results of the present article as well as those reported in Naveh-Benjamin (2000, 2002) and in other previous studies (e.g., Craik, 1983, 1986) support such a view by showing both age and DA to have a clear detrimental effect on memory for item information. The associative deficit, however, which seems to be unique to older adults, further degrades their memory performance whenever explicit episodic memory is involved. It does not seem to further affect younger adults under DA conditions.

Such a suggestion is consistent with evidence and models emerging from the literature on neuropsychology and neuroscience. For example, one noteworthy model is the one suggested by Moscovitch (1992) that proposes that episodic-memory performance is mediated by two principal components: a modular medial-temporal-hippocampal (MTL-H) component that performs operations that are essentially automatic and a frontal-lobe component that performs operations that are strategic, organizational, and accessible to consciousness and voluntary control. Recent neuroimaging studies indicate that DA at encoding mostly results in decreased brain activation in the left prefrontal region but not in the MTL-H regions (N. D. Anderson et al., 2000; Fletcher et al., 1995). Such studies are in line with the results reported in this article, showing no differential effects of DA on associative

information; they are also consistent with the notion that the MTL-H region, thought to mediate the merging of different components of an episode into a cohesive unit (Cohen & Eichenbaum, 1993), is not differentially affected by DA at encoding. Interestingly, neuroimaging studies (e.g., Mitchell, Johnson, Ray, & D'Esposito, 2000) do show that age may have some effect not only on the prefrontal regions but also on the MTL-H activity. In addition, Raz, Gunning-Dixon, Head, Dupuis, and Acker (1998) have shown significant hippocampal changes within older adults as a function of their age. This is consistent with the results reported by Naveh-Benjamin (2000) and in the experiments reported in this article, showing a disproportionately larger deficit in memory for associative than for item information.

Specification and Clarification of an ADH

Despite the support for an associative deficit underlying some of the older adults' deficits in episodic memory, at this time there are some issues and questions left open regarding different aspects of an ADH. One question is whether such a deficit shown by older adults stems mostly from problems in creating new associations during encoding or from problems in retrieving such associations at test. There are some indications that the deficit is related to both. The results reported in this study may be taken to support such a view: It seems reasonable that both processing stages might be affected by manipulations of the relatedness of the pairs, as this factor is involved both at encoding and at retrieval (Crossley & Hiscock, 1992). The results reported by Naveh-Benjamin (2000) showing a differential associative deficit in older adults, which was affected by manipulations both at encoding (instructions) and at retrieval (test types), support the conclusion that older adults' deficient memory for associations is due to problems both at encoding and in explicit retrieval. There is, however, a definite need for further research on this issue.

A second question concerns the distinction between memory for associative versus item information. Item recognition is known to rely, at least partially, on the association created between an item and the experimental context (e.g., Tulving & Thomson, 1973). If a notable characteristic of older adults is their inability to encode and retrieve associations, as suggested by the ADH, then why is item recognition also not hampered in older adults? Such a claim is not incompatible with the view presented in this article. First, the association between the item and the experimental context may be one of the mediators in the rather moderate effects of age on item recognition, reported in the literature and in the present experiments. The claim advanced by the ADH is that pair recognition more distinctly taps associative information, as it is sensitive not only to the relationships between the pairs and the experimental context (as in item recognition) but even more so to the specific relationships between the components of each pair. In addition, it seems that the associative deficit is especially relevant when the task involves explicit retrieval of associations, as is the case in the associative-recognition task. Item-recognition tests usually do not involve explicit retrieval of associations between the item and the context. The large deficits that older adults show in source (McIntyre & Craik, 1987) and context memory (Spencer & Raz, 1995) are consistent with this position, as the tasks used to demonstrate these deficits rely on explicit retrieval of associations between the item and the context.

Another important question is whether the associative deficit demonstrated in the present experiments affects or is mediated by the type of the associative representation created? We do not yet know whether older adults' memory representations of associations are different from those of younger adults. Is the associative deficit of older adults related to episodic components being represented independently in memory, unlike the memory of younger adults who have a new compound representation, qualitatively different from the separate components? Future research may shed some light on this issue (see Rizzuto & Kahana, 2001, for a related discussion).

Finally, as pointed out in the original formulation (Naveh-Benjamin, 2000), whereas an 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 may involve a reduction in priming transmitted across connections among units because of declined linkage strength (MacKay & Burke, 1990), a decreased efficiency of the simultaneity mechanism (Salthouse, 1996), or an inefficient binding mechanism (Chalfonte & Johnson, 1996; Mitchell, Johnson, Raye, & D'Esposito, 2000; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000). We believe that any such microlevel mechanism would have to account for the inefficiency in creating new associations as well as for the decreased ability to retrieve such associations.

To summarize, the present study lends additional support to an ADH, which suggests that an important factor in older adults' deficient episodic-memory performance is their difficulty in merging different aspects of an episode into a cohesive unit. The studies reported here extend the type of stimuli (pictures) under which older adults show this associative deficit. In addition, the results of the studies are in line with predictions made by an ADH; specifically, older adults seem to show less of a deficit when the components of the episodes are already connected in memory, which facilitates their encoding and retrieval. This associative deficit does not seem to be mediated by a deficit in attentional resources.

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Call for Nominations

The Publications and Communications (P&C) Board has opened nominations for the editorships of *Comparative Psychology*, *Experimental and Clinical Psychopharmacology*, *Journal of Abnormal Psychology*, *Journal of Counseling Psychology*, and *JEP: Human Perception and Performance* for the years 2006–2011. Meredith J. West, PhD, Warren K. Bickel, PhD, Timothy B. Baker, PhD, Jolida C. Hansen, PhD, and David A. Rosenbaum, PhD, respectively, are the incumbent editors.

Candidates should be members of APA and should be available to start receiving manuscripts in early 2005 to prepare for issues published in 2006. Please note that the P&C Board encourages participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. Self-nominations also are encouraged.

Search chairs have been appointed as follows:

- *Comparative Psychology*, Joseph J. Campos, PhD
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- *Journal of Abnormal Psychology*, Mark Appelbaum, PhD, and David C. Funder, PhD
- *Journal of Counseling Psychology*, Susan H. McDaniel, PhD, and William C. Howell, PhD
- *JEP: Human Perception and Performance*, Randi C. Martin, PhD

To nominate candidates, prepare a statement of one page or less in support of each candidate. Address all nominations to the appropriate search committee at the following address:

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The first review of nominations will begin December 8, 2003. The deadline for accepting nominations is **December 15, 2003**.