Psychonomic Bulletin & Review
2004, 11 (6), 1067-1073

Older adults' associative deficit in episodic memory: Assessing the role of decline in attentional resources

MOSHE NAVEH-BENJAMIN
University of Missouri, Columbia, Missouri

and

JONATHAN GUEZ and SHLOMIT SHULMAN
Ben-Gurion University of the Negev, Beer-Sheva, Israel

In this study, we evaluated an associative deficit hypothesis. This hypothesis suggests that the deficit seen in the episodic memory performance of older adults is due, in considerable part, to older adults' difficulty in binding together unrelated components of an episode into a cohesive entity (Naveh-Benjamin, 2000). The study extended the conditions under which older adults show a differential deficit in tests requiring associations among the episode components to situations in which the item and the associative recognition tests are equated on the response mode used and on the amount of information displayed. In addition, we tested the potential role of a decrease in attentional resources in the associative deficit of older adults by comparing their performance to that of younger adults under conditions of reduced attentional resources. The results of the study, which indicate that younger adults under divided attention do not show an associative deficit, are interpreted as indicating that the associative deficit of older adults is due to factors other than depleted attentional resources.

Numerous studies (e.g., Craik & Jennings, 1992) show that memory declines with old age. However, this decline seems to be differential, affecting only some memory functions. Episodic memory seems to be especially vulnerable to the effects of age (see, e.g., Light, 1991). Researchers have tried to explain the mechanisms underlying the age-related decline in episodic memory, and several hypotheses have been advanced to explain the relatively poor memory performance of the old (see Light, 1991, for a review).

Recently, a binding deficit hypothesis has been suggested. Chalfonte and Johnson (1996) and Mitchell, Johnson, Raye, Mather, and D'Esposito (2000) showed that older adults are particularly deficient in memory that requires the binding of information to contextual elements. Naveh-Benjamin (2000) proposed an associative deficit hypothesis (ADH) which focuses on the distinction between memory for single units and memory for association among units. The hypothesis is based on the notion that complex episodes consist of multiple kinds of information sources that are related to each other. Remembering such an episode requires that at least some of the components, as well as their relationships to each other, be retained. The ADH claims that a major factor in older adults' poorer episodic memory is the difficulty they encounter in creating and retrieving links between single units of information.

Naveh-Benjamin (2000) used tasks that allow the independent assessment of memory for item (component) and for associative information. Under such procedures (see Humphreys, 1976), younger and older adults study a list of pairs of items and are then given two tests. One test is on item information, in which participants are shown some of the original items with some new items and their task is to recognize the old items. Another test is on associative information. In this test, participants receive some pairs that appear intact and as originally presented in the study phase, and some recombined pairs which include one item taken from one previously presented pair and another item from a different pair. Participants must recognize which of the pairs appears in its original form.

The four experiments conducted by Naveh-Benjamin (2000) provide the ADH with convergent validity by demonstrating that an associative deficit exists in older adults for both interitem relationships and intraitem relationships (an item and its context), and discriminant validity by showing that when competing predictions are contrasted, the results support the ADH over a number of alternative hypotheses, including those pertaining to contextual encoding and retrieval deficits.

This research was supported in part by grants from the Ben-Gurion University Faculty of Humanities and Social Sciences and from the Zlotowski Center for the Neurosciences to M.N.-B. Parts of the manuscript were written while the first author was a visiting scientist at the Rotman Research Institute, Baycrest Centre for Geriatric Care, Toronto. We thank Marcia Johnson for helpful comments on an earlier version of this article. Correspondence concerning this article should be addressed to M. Naveh-Benjamin, Department of Psychological Sciences, University of Missouri, 106 McAlester Hall, Columbia, MO 65211 (e-mail: navehbenjaminm@missouri.edu).

The present study is intended to provide further tests of the ADH. First, since Naveh-Benjamin's (2000) study is one of the few in the aging literature that have shown the associative deficit of older adults using an associative recognition paradigm, we wanted to replicate it in order to strengthen the empirical support for the ADH. Second, we wanted to test whether reduction in attentional or processing resources, which has been suggested as an underlying cause of older adults' decline in episodic memory (see, e.g., Craik & Byrd, 1982), may be a mediating factor in the associative deficit of older adults. In order to test this idea empirically, these researchers suggested testing younger adults performing under a divided attention (DA) condition. In such a condition, young participants are also operating with reduced attentional resources, since part of their resources are directed toward performing the secondary task; therefore, their performance should simulate the memory performance patterns of older adults. Several studies in the literature, in which younger adults under DA conditions showed patterns of memory performance decline similar to those of older adults (e.g., Craik & Byrd, 1982; Rabinowitz, Craik, & Ackerman, 1982), supported this suggestion.

To assess whether reduction in attentional resources is indeed a mediating factor in the age-related associative deficit, in the experiment reported here we tested not only younger and older adults under full attention conditions, but also younger adults under DA conditions. If the associative deficit shown in older adults is mediated by a decline in attentional resources, we would expect younger adults under DA conditions to show the same associative deficit as that predicted for older adults.

Finally, we wanted to rule out the possibility that the results reported by Naveh-Benjamin (2000) were due to differences in the amount of information displayed in the different memory tests administered. In particular, in Naveh-Benjamin's (2000) study, in each of the experiments in which performance on item and associative recognition was compared, each test item in the item recognition test (in a yes–no format) included only one word (a target or a distractor), whereas each test item in the associative recognition test included two words (intact or recombined word pairs). This was done in order to equate the response mode used by the participants in each test: They responded "yes" to recognized information (a target in the item test and an intact pair in the associative test) and "no" to unrecognized information (distractors in the item test and recombined pairs in the associative test). Such a procedure, however, leaves open the possibility that older adults perform more poorly in the associative recognition test because this test displays more information per event (two words) than the item recognition test does (one word), making it more difficult. To test this possibility, we equated the amount of information presented in each display of each of the tests by using, in addition to the standard yes–no item recognition test, a forced-choice item recognition format in which each test item included two words (a target and a distractor) and in which the participants were asked to identify the one that had appeared in the study phase. We wanted to see if the associative deficit shown by the older adults would also be evident when the amount of information presented in both the item and the associative recognition tests was equated.

METHOD

Participants

There were 44 participants, of which 22 were younger and 22 were older adults. The participants in the younger age group were undergraduate students at Ben-Gurion University who took part in the experiment for course credit. The older age group consisted of participants recruited from the Beer-Sheva community. The mean age of the young group was 23.8 ($SD = 2.3$), and the mean age of the older group was 81.2 ($SD = 4.2$). All the participants had normal vision and hearing abilities for their age, as was indicated in self-reports and in their ability to report standard stimuli presented to them visually and auditorily. In addition, the participants all reported being in good health.

Design

Two independent variables were used: group (young–full attention, young–DA, within-subjects, and older adults)[1] and test (yes–no item recognition, forced-choice item recognition, and associative recognition).

Materials

The study stimuli were four lists of 34 pairs of words that were not related visually, semantically, or auditorily. The words were high-frequency Hebrew common nouns. For each list, two versions of pairings were created and two random orders were used for each of these pairings, for a total of four versions. Five or 6 participants in each age group were run in each version. The young participants were shown all four lists (two under full attention and two under DA), whereas the older adults were randomly shown two of the four lists. The order of the lists was counterbalanced for both age groups, whereas the order of the attention conditions was counterbalanced for the younger adults.

Procedure

The participants, who were tested individually, saw 34 word pairs on a computer monitor, 1 at a time, at a rate of 5 sec per pair for the young participants and 8 sec per pair for the older participants (the different rates were used to lower the younger adults' performances below ceiling levels; see Rabinowitz et al., 1982, for a similar procedure). The test called for intentional study, and the participants were instructed to pay attention not only to each item but also to the pairs, because their memory for both items and pairs would be tested. The young participants performed a secondary task during the study phase of two of the lists. This task involved the auditory presentation via a tape recorder of single-digit pairs, one every 2 sec. Fourteen of these participants judged and orally reported whether each of the digits was an odd or an even number, whereas 8 participants received a slightly different secondary task in which they were asked to judge whether the second digit in each pair was larger or smaller than the first one. Since there were no differences in performance in the memory task under each of the secondary task versions, the reported data were combined. Prior to the study phase of each of the DA trials, the participants were told to pay equal attention to memorizing the words and to performing the secondary digit task.

Each list was followed by an interpolated activity of 60 sec in which the participants counted backward in threes from a given number; then, the three memory tests described below (two item tests and one association test) were administered to all the participants. The order of the tests was counterbalanced across all participants in each group, and each word appeared in only one of the tests.

Yes–no item recognition test. In this test, the participants saw 16 words, 1 at a time. Of these, 8 were targets and 8 were distractors, and they were mixed randomly. For each participant, the targets words were selected at random from 8 of the studied pairs (1 from each pair). The distractors were 8 words with the same characteristics as the target words, except that they had not appeared in the study phase. The participants were told that 8 of the words had appeared in the study phase and were instructed to respond to these words with a designated "yes" response key.

Forced-choice item recognition test. In this test, the participants saw 16 original target words, 1 at a time, each paired with a distractor word that had the same characteristics as the target word except that it had not appeared in the study phase. For each test pair, the participants were asked to indicate which of the words had appeared in the study phase.

Associative recognition test. In this test, 16 word pairs, selected randomly for each participant, were presented visually, 1 at a time. Eight of them were intact pairs from the study phase—that is, pairs of words that had appeared together in the study phase. The other 8 pairs were recombined (rearranged) pairs—that is, they consisted of words taken from different study pairs. The participants were told that all the items had appeared in the study phase and that their task was to respond "yes" to the 8 pairs that had appeared as such in the study phase.

Prior to the study session, all the participants were given a practice session in which they rehearsed all the relevant tasks.

RESULTS

Measures of proportion of hits minus false alarms were computed for each participant and then averaged over each group for the yes–no item and associative recognition tests. (Separate hit and false alarm rates in the yes–no item and associative recognition tests for each group appear in Table 1.) In order to make the performance scale in the forced-choice item recognition test equivalent to the hits-minus-false-alarms scale on the associative recognition test, we transformed the mean proportion correct responses in the forced-choice item recognition test for each participant, using the formula (proportion correct − .5)/.5. This equated the item and associative recognition tests with respect to the scale used (from chance level performance at 0 to the highest possible score of 1).

To specifically address the hypotheses tested in this experiment, several separate 2 (group) × 2 (test) analyses of variance (ANOVAs) were computed on the memory measure. The .05 level of significance was used to interpret all of the statistical comparisons. In order to evaluate the associative deficit, for each analysis we first compared group performance on the associative recognition test to that on the yes–no item recognition test, and then to that on the forced-choice item recognition test.

Figure 1 presents results of memory performance on the different tests in the young–full attention and the older adult groups. To test the ADH for the older adults, a 2 (group: young–full attention vs. older adults) × 2 (test: yes–no item recognition vs. associative recognition) ANOVA was performed. The results indicate a significant effect of group [$F(1,42) = 86.26$, $MS_e = .04$], in which the young group under the full attention condition (.71) performed better than the older group (.31). The effect of test was not significant [$F(1,42) = .82$, $MS_e = .04$]. More important, the interaction of the two variables was significant [$F(1,42) = 23.01$, $MS_e = .04$]. This reflects the fact that the older adults were disproportionately impaired on the association test (.19) relative to the item test (.44) in comparison with the young adults, who showed the opposite pattern (.80 and .64 for the associative recognition and item recognition tests, respectively).

A similar ANOVA was computed using the forced-choice item recognition test and the associative recognition test, and it yielded similar results. First, the results indicate a significant effect of group [$F(1,42) = 68.75$, $MS_e = .06$], in which the young group under the full attention condition (.79) performed better than the older group (.36). The effect of test was also significant [$F(1,42) = .14.55$, $MS_e = .04$], with performance on the item test (.65) being better than that on the associative test (.48). The interaction of the two variables was significant [$F(1,42) = 21.46$, $MS_e = .04$]. This, again, reflects the fact that the older adults were disproportionately impaired on the association test (.19) relative to the item test (.54), unlike the young adults, who showed equal performance on both tests (.80 and .77 for associative and item tests, respectively).

Figure 2 presents results of memory performance on the different tests in the young group under full attention and DA conditions. To test the ADH for the young adults under DA conditions, a 2 (condition: young–full attention vs. young–DA) × 2 (test: yes–no item recognition vs. associative recognition) ANOVA was computed. The results indicate a significant effect of attention [$F(1,21) = 48.61$, $MS_e = .05$], in which the young adults performed better under the full attention condition (.71) than under the DA

Table 1
Means and Standard Deviations for Proportion Hits and False Alarm Rates in the Yes–No Item Recognition and Associative Recognition Tests in Each of the Experimental Groups

	Item Recognition Test				Associative Recognition Test			
	Hits		False Alarms		Hits		False Alarms	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Young–full attention	.78	.14	.14	.09	.90	.12	.10	.11
Young–divided attention	.66	.16	.30	.21	.68	.20	.28	.20
Older adults	.60	.21	.16	.16	.53	.23	.34	.21

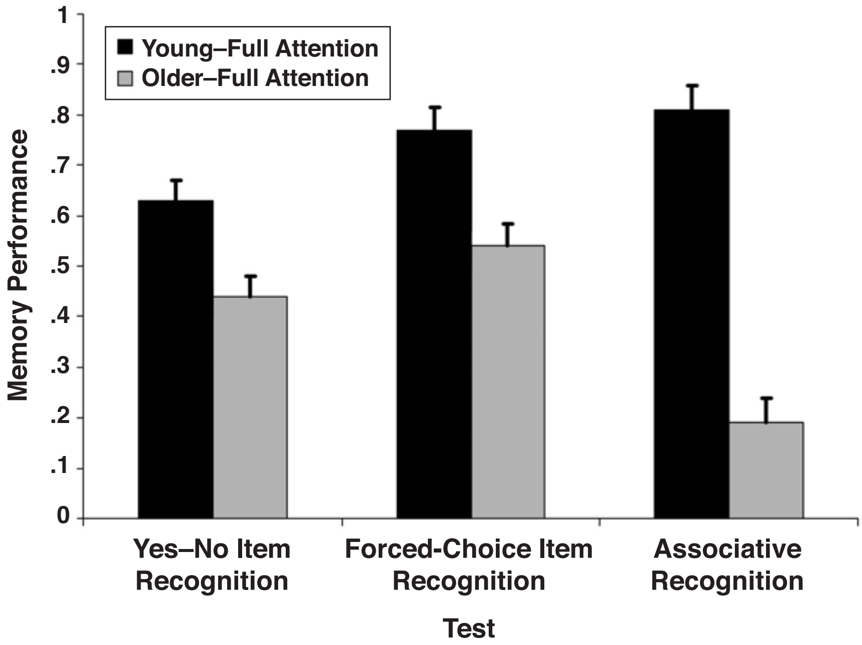

Figure 1. Memory performance (plus *SE*s) in the item and associative recognition tests for young and older adults under full attention conditions.

condition (.37). The effect of test was not significant [$F(1,21) = 3.60$, $MS_e = .07$, $p > .05$]. More importantly for the ADH, the interaction of the two variables was not significant [$F(1,21) = 2.91$, $MS_e = .03$, $p > .1$], reflecting an equal decline in performance from the full attention to the DA conditions in the item and the associative tests.

A similar ANOVA was computed using the forced-choice item recognition test and the associative recogni-

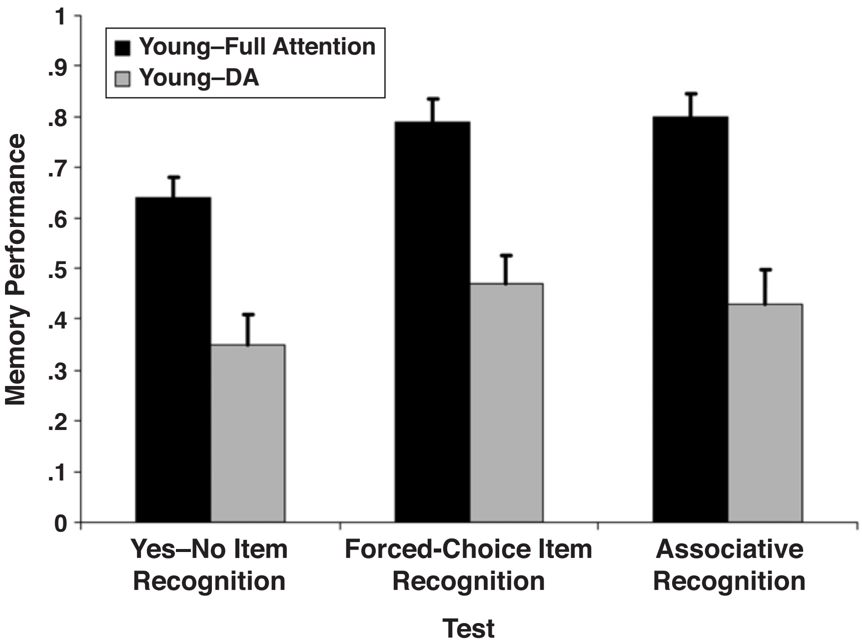

Figure 2. Memory performance (plus *SE*s) in the item and associative recognition tests for young adults under full attention and divided attention (DA) conditions.

tion test, with similar results. First, there was a significant effect of attention [$F(1,21) = 64.07$, $MS_e = .04$], in that the young participants performed better under the full attention condition (.79) than they did under the DA condition (.43). Second, the effect of test was not significant [$F(1,21) = .21$, $MS_e = .04$]. Finally, the interaction of the two variables was not significant [$F(1,21) = 1.23$, $MS_e = .05$], reflecting an equal decline in performance from the full attention condition to the DA condition in the item and associative tests.

Finally, Figure 3 presents results of memory performance on the different tests in the young group under DA conditions and the older adult group. When performance of the young adults under DA conditions was compared to that of the older adults on the yes–no item recognition and associative recognition tests, the 2 × 2 ANOVA yielded no significant effect of group [$F(1,42) = .94$, $MS_e = .09$], in that the young DA group (.37) performed as well as the older adult group (.31), or of test [$F(1,42) = 3.62$, $MS_e = .07$, $p > .05$]. More important, the effect of the interaction was significant [$F(1,42) = 6.88$, $MS_e = .07$]. This interaction reflects the fact that the older adults performed more poorly on the associative test than on the item test (.19 and .44, respectively), whereas the young adults under DA showed the same level of performance in the two tests (.39 and .35 for associative and item recognition, respectively).

A similar ANOVA that was computed using the forced-choice item recognition and the associative recognition tests showed similar results. This 2 × 2 ANOVA yielded no significant effect of group [$F(1,42) = 1.09$, $MS_e = .10$], a significant effect of test [$F(1,42) = 15.85$, $MS_e = .06$, $p > .05$], and a significant interaction [$F(1,42) = 6.76$, $MS_e = .06$]. This interaction reflects the fact that the older adults performed more poorly on the associative than on the item test (.19 and .54, respectively), relative to the young adults under DA conditions, who showed the same level of performance in the two tests (.40 and .47 for associative and item recognition, respectively).

DISCUSSION

The results reported in this manuscript extend the empirical support for the ADH and clarify the role of attention in the associative deficit. Rather than showing a generalized decrement in memory, the older adults showed specific deficits in memory for associative information (see Naveh-Benjamin, 2000, 2002; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003). This deficit cannot be explained by the differences in the amount of information or by the differences in the response mode in the item and the associative tests; older adults show the deficit in the associative recognition task when it requires the same response mode as the item recognition task (yes–no response) and when the amount of information displayed in the associative recognition test is equal to that in the item recognition test (forced-choice with two alternatives). The present results also extend the associative deficit to a broader age range, given that our older adults were about 6 years older than those reported in the previous studies mentioned above.

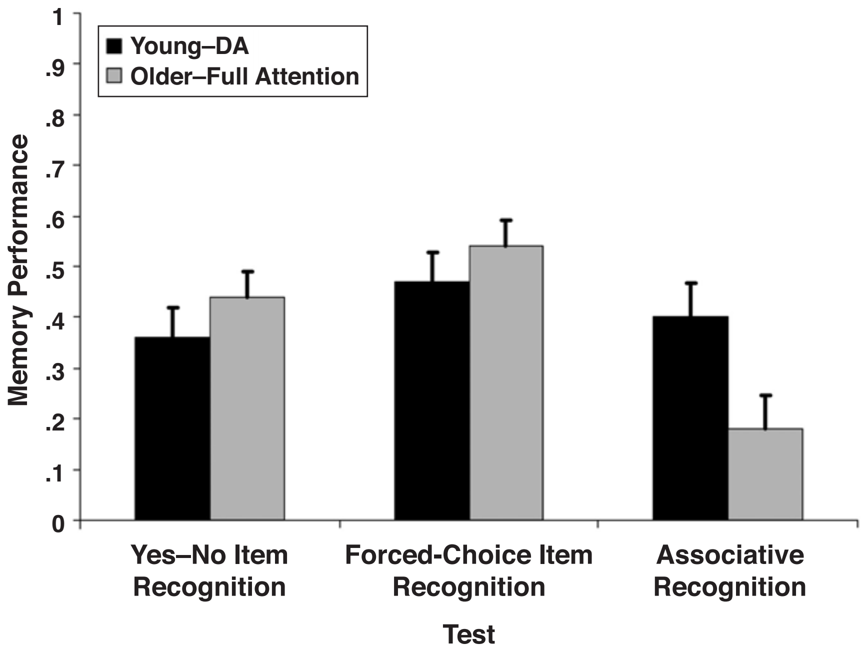

Figure 3. Memory performance (plus *SE*s) in the item and associative recognition tests for young adults under divided attention (DA) and older adults under full attention conditions.

Furthermore, in contrast to previous studies (e.g., Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, et al., 2003), the older adults' associative deficit was demonstrated here when performance levels in the young adults were either equal for the item and associative recognition tests or better in the associative test (when yes–no item recognition was used). Such comparable performance on the two tests has been shown elsewhere for younger adults (Hockley, 1992; Naveh-Benjamin, Guez, & Marom, 2003) and may be related to the difficulty of the distractors used in the item test. Such a pattern reduces the possibility that the differential effects for younger and older adults are due to differences in the difficulty of the two tests, extending the conditions under which the effects are demonstrated. Finally, the older adults suffered from an associative deficit despite the fact that they had more time (8 vs. 5 sec) to encode each word pair.

In this experiment, we also tested the younger adult group under DA conditions at encoding. The results showed that, unlike age, DA has the same disruptive effect on memory for both the components of the episode and their association with each other. The different performance patterns demonstrated by older adults and younger adults under DA conditions, despite the generally similar level of performance in the two groups, shows the specificity of the older adults' deficit. These results do not support the suggestion that the associative deficit of older adults stems from a special reliance of the encoding of associative information on attentional resources. Also, the lack of differential effects of DA on associative recognition does not seem to be due to the specific secondary task used here (but see a recent article by Castel & Craik, 2003). This secondary task, which involved the processing of numerical information, was demanding enough, leading to a significant overall decrement of almost 50% in memory performance relative to the full attention condition.

The present results provide boundary conditions to the proposal that reduced attentional resources may be a common mechanism underlying the effects of age and DA on episodic memory (see, e.g., Craik & Byrd, 1982). Although both DA in the young and age are associated with poorer episodic memory performance, the loci of their effects seem to be somewhat different. Aging seems especially to disrupt the associative mechanism, whereas reduced attention at encoding in younger adults leads to a general decrease in memory performance.

The lack of differential reduction in associative memory in younger adults under DA at encoding suggests that whatever processes were disrupted during DA were not the ones that account for the creation of associations. This raises the possibility that attention is not necessary for binding (see recent results by Naveh-Benjamin, Guez, & Marom, 2003). An alternative possibility, which should be studied in the future, is consistent with the notion of varieties of attention (see, e.g., Johnson, 1992) and suggests that the secondary task used in this study did not disrupt the type of attention that mediates the creation of associations.

One explanation for the discrepancy between the results on age-related changes in the older participants and the effects of DA in the young participants is that both common and distinctive factors affecting memory performance are at work in these two groups. Depleted attentional resources may be a mechanism that operates both in older adults and in younger adults under DA at encoding. The results reported here, as well as those of previous studies (Craik & Byrd, 1982; Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, & Marom, 2003; Naveh-Benjamin, Hussain, et al., 2003; Rabinowitz et al., 1982), which show that both age and DA have a clear detrimental effect on memory performance, support such a view. Similarly, studies with younger adults in which the response deadline procedure was used in the test phase show that their performance becomes similar to that of older adults, mostly due to the interruption of recollection processes (see, e.g., Jacoby, 1999). Older adults, however, seem to have an additional unique associative deficit, which further degrades their memory performance whenever explicit episodic memory is involved. This component of the episodic memory loss in older adults seems not to be resource dependent, since it does not seem to affect younger adults under DA conditions.

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NOTE

1. To increase the power of the test, we used a within-subjects design for the attention manipulation. This did not pose problems for the statistical analysis, since the evaluation of the relevant questions involved pairwise group comparisons.

(Manuscript received July 21, 2003;
revision accepted for publication January 26, 2004.)