Psychology and Aging
2003, Vol. 18, No. 4, 873–885

0882-7974/03/$12.00 DOI: 10.1037/0882-7974.18.4.873

The Effects of Aging and Divided Attention on Memory for Item and Associative Information

Alan D. Castel
University of Toronto

Fergus I. M. Craik
Rotman Research Institute and University of Toronto

The present study examined how aging and divided attention influence memory for item and associative information. Older adults and younger adults working under full-attention conditions and younger adults working under divided-attention conditions studied unrelated word pairs. Memory for item information was measured by later recognition of the 2nd word in the pair, and associative information was measured by recognition of the entire pair. Both older adults in the full-attention condition and younger adults in the divided-attention condition performed more poorly than younger adults in the full-attention condition, with the deficit in associative information being greater than the deficit in item information. In addition, a differentially greater associative decrement was found for the older adults, as shown by their heightened tendency to make false-alarm responses to re-paired (conjunction) distractors. The results are discussed in terms of an age-related reduction in processing resources compounded by an age-related increase in older adults' reliance on familiarity in associative recognition memory.

The distinction between item information and associative information has a long history in psychology, and this distinction has been examined extensively in both theoretical and empirical studies of human memory (Anderson & Bower, 1973; Hockley & Cristi, 1996; Humphreys, 1976; Murdock, 1982, 1993). The items in question are typically well-integrated stimuli such as words, letters, numbers, or pictures, whereas associative information refers variously to the formation of new items by binding features together, to the links among several items, or to the integration of an event with its context of occurrence. The actual mechanism of integration or binding is still poorly understood, although it has been suggested that successful binding involves conscious attentional processes mediated by the frontal lobes as well as more automatic processes mediated by medial–temporal structures (Moscovitch, 2000; Moscovitch & Winocur, 1992). If conscious attentional processing is a prerequisite for binding, then an impairment of such processing should lead to inefficient binding and poor formation of associations.

Craik has suggested that normal aging is accompanied by a reduction in attentional resources (Craik, 1983; Craik & Byrd, 1982; Craik & Simon, 1980), so it should follow that older adults are less able to bind features together, to form new associations, and to integrate items with their contexts of occurrence. There is strong evidence in favor of all of these effects. Chalfonte and Johnson (1996) have suggested that part of older adults' impaired memory performance stems from their reduced efficiency in binding information into a coherent complex memory. Similarly, Naveh-Benjamin (2000) has proposed an associative deficit hypothesis that states that older adults have poorer memory because of a deficiency in creating and retrieving links between single units of information. Furthermore, an age-related decrement in memory for the context or the source of information has been well established (McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991; Spencer & Raz, 1995). By the same argument, division of attention in young adults should also lead to an impairment in various types of associative information, and again there is strong evidence to support this claim. Craik, Govoni, Naveh-Benjamin, and Anderson (1996) showed that division of attention at the time of encoding greatly reduced subsequent cued recall for unrelated noun pairs (i.e., the first noun served as the cue for the second), and this reduction may be attributed to a failure to establish an adequate associative linkage between the component items. Further experiments have shown deficits in memory for contextual information when young adults perform under conditions of divided attention (Troyer & Craik, 2000; Troyer, Winocur, Craik, & Moscovitch, 1999). It seems then that division of attention and aging have similar effects, and these similarities may stem from a reduction in available attentional resources in both cases (Craik, 1982, 1983; Rabinowitz, Craik, & Ackerman, 1982).

However, there is also evidence that calls into question the equivalence of aging and divided attention. In a recent series of experiments, Naveh-Benjamin, Guez, Givati, and Marom (2001; see also Naveh-Benjamin, 2001; Naveh-Benjamin & Guez, 2002)

Alan D. Castel, Department of Psychology, University of Toronto, Toronto, Ontario, Canada; Fergus I. M. Craik, Baycrest Centre for Geriatric Care, Rotman Research Institute, Toronto, Ontario, Canada, and Department of Psychology, University of Toronto.

This research was supported by a Natural Sciences and Engineering Research Council of Canada (NSERC) grant to Fergus I. M. Craik and by an NSERC postgraduate fellowship to Alan D. Castel as well as financial support from Soroptimists International of Toronto. We thank Darlene Howard, Michael Humphreys, Jill Locantore, and Mark Tippens Reinitz for many useful comments on a previous version of this article. We also thank Sharyn Kreuger, Nicole Jordan, and Nick Turk-Browne for help with the experiments.

Correspondence concerning this article should be addressed to either Alan D. Castel or Fergus I. M. Craik, Department of Psychology, University of Toronto, 100 Saint George Street, Toronto, Ontario M5S 3G3, Canada. E-mail: alan@psych.utoronto.ca or craik@psych.utoronto.ca

found different patterns of impairment between older adults and younger adults working under conditions of divided attention. Specifically, these researchers showed that whereas older adults exhibited a differentially greater decrement (relative to their younger counterparts) in associative information than in item information, division of attention in younger adults resulted in equivalent deficits in item and associative information. This result is in line with Naveh-Benjamin's (2000) suggestion that aging is particularly detrimental to memory for associative information and suggests that there are distinct differences between aging and division of attention in young adults. One major purpose of the present study was to explore these differences in greater detail.

The idea that the impaired encoding and retrieval of associative information lead to a reduction in overall memory performance has been examined in a variety of tasks. It has been suggested that at least some false memories are caused by binding failures, such that components of presented information are inappropriately or incorrectly recombined to form episodes that have not happened (Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996). The errors that result from the inappropriate combination of processed information are known as *memory conjunction errors*, and these errors can be found when one encounters faces, pictures, sentences, or word pairs (Reinitz, Verfaellie, & Milberg, 1996). Reinitz, Lammers, and Cochran (1992) found that participants would often claim to have seen a new stimulus if it had been constructed from parts of previously studied stimuli. For both faces and two-syllable nonsense words, participants made more false-alarm responses to conjunction stimuli that were constructed entirely from parts of previously studied stimuli than they did to either partially or completely new stimuli. Reinitz, Morrissey, and Demb (1994) found that participants under divided-attention conditions were more susceptible to the false claim that conjunction faces were previously seen during an encoding phase, further supporting the notion that attention is needed to encode relational or associative information about features. Similarly, Naveh-Benjamin (2000) showed that normal aging is characterized by a diminished ability to discriminate between correctly and incorrectly re-paired items in a recognition memory test.

Another way to describe the manner in which item and associative recognition occurs is based on a dual-process model that is used to account for feature and conjunction errors (e.g., Jones & Jacoby, 2001; Jones, Jacoby, & Gellis, 2001). According to the model, dissociations between old item recognition and feature and conjunction errors support the familiarity–recollection account of recognition memory. Specifically, old word recognition is based on the processes of familiarity and recollection working in concert, whereas feature and conjunction errors are based on familiarity in the absence of recollection. Several sources of evidence suggest that recollective processes are more impaired than familiarity processes in old age (see Light, Prull, La Voie, & Healy, 2000, for a review). Jones and Jacoby (2001) pointed out that several manipulations have been shown to affect hit rates but not feature and conjunction error rates after the baseline false-alarm rates to new words are subtracted out. It is interesting that two of these variables are divided attention at study (Reinitz et al., 1994) and normal aging (Rubin, Van Petten, Glisky, & Newberg, 1999; but also see Kroll et al., 1996). In general, Jacoby, Jennings, and Hay (1996) showed that by using the process dissociation procedure, divided attention and aging influenced controlled processes such as recollection, whereas more automatic processes such as familiarity were not affected to the same degree.

In summary, the present study was undertaken with various goals in mind. First, we wanted to compare the effects of aging on the recognition of item and associative information, with the expectation that associative information would be more detrimentally affected (Naveh-Benjamin, 2000). Second, we wanted to compare the effects of divided attention on item and associative information. If divided attention mimics aging, then associative information should again be more detrimentally affected, but to replicate the results of Naveh-Benjamin and Guez (2002) and Naveh-Benjamin et al. (2001), we should find that divided attention has equivalent effects on recognition of the two types of information.

Experiment 1A

Is it the case that aging has a differentially greater negative effect on associative information than on item information, whereas division of attention equally affects both types of information? To answer this question, we presented three groups of participants—younger adults under full attention, younger adults under divided attention, and older adults under full attention—with unrelated word pairs during an encoding phase and then gave them two recognition tests. Participants were presented with four types of word pairs during the recognition tests: old word pairs, word pairs that contained two previously presented words but that were never presented together as a pair (conjunction pairs), word pairs with one old word and one new word (item pairs), and word pairs that contained two new words (new pairs). Participants in the divided-attention condition also engaged in a secondary digit-monitoring task during the encoding phase only. In the word-pair recognition test, participants were asked to identify old word pairs that they had previously seen during the encoding phase. The pattern of "old" responses for the old and conjunction word pairs for the three groups of participants was of primary interest. If older adults and younger adults under divided-attention conditions have difficulty processing the association between the two words during encoding, then they should show a higher number of old responses (false alarms) to conjunction word pairs and a lower number of old responses (hits) to old word pairs relative to the younger participants in the full-attention condition. If older adults have a particular difficulty with associative information, they should be less able than divided-attention younger adults to discriminate between old (original) and conjunction (recombined) word pairs.

To test for the retention of item information under conditions similar to those used for associative information, we gave participants a similar recognition test (consisting of the same four types of word pairs as those used in the associative memory test), but in this case participants decided whether they had previously seen the *second word* in a presented pair during the encoding phase. In this item test, therefore, both old pairs and conjunction pairs were potential hits, as the second word had occurred previously. In contrast, only old pairs were potential hits for the associative test; all other test types were potential false alarms. If pairs presented during encoding are represented as A–B and C–D and if words not presented at study are represented as X, Y, and Z, then the four types of test pairs may be represented as A–B (old), A–D (conjunction), A–X (item), and Y–Z (new). For the associative test only, A–B test pairs should be judged “old,” whereas for the item test, both A–B and A–D pairs should be judged “old.”

A further benefit of this design in the case of item information is that the effects of context on the recognition of items can be examined. Both A–B pairs (old) and A–D pairs (conjunction) include old items (B and D), but recognition of B may be superior given that it is presented in the same pair context (A–B) at test as at encoding. Such a result would be in line with previous findings in this paradigm (Humphreys, 1976, 1978; Light & Carter-Sobell, 1970; Tulving & Thomson, 1973), and the extent of the superiority of A–B over A–D would provide a measure of the extent to which participants use context information to enhance recognition performance. If younger adults bind items to their contexts (at encoding) more successfully than either older adults or younger adults under divided attention, it would be expected that the superior recognition of B over D would be greatest for younger adults working under full-attention conditions. This allows for an examination of the effects of aging and divided attention on possible differences between *recognition* of context (i.e., old vs. conjunction pairs in the case of pair recognition) and *utilization* of context (i.e., old vs. conjunction pairs in the case of item recognition). Furthermore, we were interested in examining the effect of the overall similarity of lures on pair recognition; for example, would participants be more likely to make false alarms as the test pairs went from new (Y–Z), to item (A–X), to conjunction (A–D) pairs, and would any such trend differ for younger and older adults?

Method

Participants. In total, 64 undergraduate students from the University of Toronto (52 women and 12 men, mean age = 21.3 years, mean number of years of education = 13.8) volunteered to participate and received course credit for their participation. Participants were randomly assigned to participate in either the full- or divided-attention condition, such that 32 students participated in each condition. Thirty-two older adults (19 women and 13 men, mean age = 70.3 years, mean number of years of education = 14.3) also participated in the study and were paid $10 (Canadian funds; approximately U.S. $7.40) for their participation. The older adults tested in this experiment and in Experiment 2 were high functioning and in good health; they lived in the community and made their own way to the laboratory to participate.

Materials. The words presented in the encoding task were 260 two-syllable common concrete nouns that were randomly paired to form 130 word pairs (e.g., A–B or C–D). Each participant was presented with 130 word pairs during the encoding phase. The word pairs were visually presented in a completely randomized order (separately for each participant) in the center of a 17-in. (43.18-cm) IBM computer screen. Each pair was presented for 4 s, with a 500-ms gap between presentations. In each of two recognition tests, 80 word pairs were presented in a randomized order. The word pairs in the recognition tests consisted of previously seen old word pairs (A–B or C–D), recombined pairs that contained two words that were previously seen but not together (A–D), pairs that contained one previously seen word in the first position and one new word in the second position (A–X), and pairs that contained two new words (Y–Z). Each word had an equal likelihood of appearing in each of the four types of word pairs, such that four different types of trials were constructed, with the word being rotated through each of the four types of word pairs. In all cases, if an old word appeared at test, it was presented in the same pair position (first or second word in the pair) as it was in the encoding phase. Twenty of each of the four types of word pairs were presented in a random order of 80 word pairs, and the presented word pair disappeared from the screen either after the participant made a response or after 4 s had elapsed. The experiment was programmed using MEL2 (Schneider, 1990), and each participant was tested individually.

The digit-monitoring task consisted of an auditory presentation of single digits ranging from 0 to 9 in a random order. Twelve hundred digits were spoken by a female voice and recorded on a tape recorder at a rate of 1 digit every 1.5 s, producing a 30-min recording. The participant’s task was to monitor the series of digits for targets, defined as “3 successive odd digits” (e.g., 391, 951, 737), and to report the targets to the experimenter. The digits occurred in a random order, with the following constraints: The recording included 80 target sequences, defined as 3 consecutive odd digits. The first 60 targets were unique, and the last 20 targets were replayed from the beginning of the recording. The lags between target sequences ranged from 6 to 19 digits, with a mean lag of 12.5 digits.

Procedure. Younger participants were randomly assigned either to the full-attention condition or to the divided-attention condition. Older adults performed the memory task under full-attention conditions only. Before the encoding task, participants were given instructions regarding the experiment. They were told that they would be presented with word pairs and were asked to try to remember the words, as well as how they were paired with one another, for a later memory test.

In the divided-attention condition, the digit-monitoring task was described to the participants. The participants were instructed to listen to the recording of digits and to identify sequences that contained three consecutive odd digits (e.g., 573) by repeating the target sequences aloud so that the experimenter could record their responses. Before the encoding phase began, participants practiced the digit-monitoring task until they correctly identified two consecutive target sequences. Participants performed the digit-monitoring task during the encoding phase only, not during the recognition tests.

After the encoding phase, participants were given two recognition tests in counterbalanced order. Each test consisted of 80 word pairs, as described above in the *Materials* section. In one test, participants were asked if they had seen the presented word pair during the encoding phase (the word-pair recognition test). That is, participants should answer “yes” only if the same words had occurred in the same order as members of a pair in the initial presentation. A second test involved determining if they had seen the second word in the presented word pair during the encoding phase (the single-word recognition test). In the word-pair recognition test, participants were told that they would be presented with a word pair and that they should read the word pair aloud and then decide if they had seen the entire word pair during the encoding phase. Participants were instructed to press the *Z* key on the keyboard (labeled *yes*) if they had previously seen the word pair in the encoding phase or the *N* key on the keyboard (labeled *no*) if they had not seen the word pair in the encoding phase. In the single-word recognition test, participants were told that a series of word pairs would be presented and that they should read each word pair aloud. This time, however, they were asked to decide if they had seen the second word in the pair during the initial encoding phase. That is, they should respond “yes” if the second word had appeared anywhere in the original encoding list, regardless of its original pairing. Again, participants were instructed to press the *Z* key on the keyboard (labeled *yes*) if they had previously seen the second word during the encoding phase or the *N* key on the keyboard (labeled *no*) if they had not seen the word during the encoding phase. These two recognition tests were presented in counterbalanced order, and none of the words in the word-pair recognition test appeared in the single-word recognition test. In each test, participants had up to 4 s to make a response, and the next trial began either after a response was made or after the 4 s had elapsed.

Results and Discussion

The results for the word-pair recognition test and for the single-word recognition tests are displayed in Table 1. In both cases, the proportions of “old” responses to each of the four types of word

Table 1

Mean Proportion of "Old" Responses to Each of the Four Word-Pair Types in the Word-Pair Recognition Test and in the Item (Single-Word) Recognition Test for Experiments 1A and 1B

	Word-pair recognition test				Single-word recognition test			
Experiment and group	Old	Conj	Item	New	Old	Conj	Item	New
Experiment 1A								
Full attention	.63 (.03)	.17 (.02)	.08 (.02)	.05 (.01)	.69 (.03)	.54 (.03)	.14 (.02)	.17 (.02)
Divided attention (encoding only)	.39 (.03)	.28 (.03)	.21 (.03)	.15 (.02)	.42 (.03)	.37 (.03)	.23 (.03)	.21 (.03)
Older	.61 (.04)	.40 (.04)	.23 (.03)	.12 (.03)	.63 (.04)	.60 (.03)	.30 (.03)	.22 (.03)
Experiment 1B								
Divided attention (encoding and retrieval)	.58 (.02)	.22 (.03)	.13 (.02)	.06 (.01)	.58 (.04)	.49 (.03)	.18 (.02)	.14 (.02)

Note. In the word-pair recognition test, hits constitute "old" responses to old word pairs, and in the single-word recognition test, hits constitute "old" responses to both old and conjunction (Conj) word pairs. Standard errors of the means are in parentheses.

pairs are shown in Table 1. In Figures 1 and 2 (for word-pair and single-word tests, respectively), false alarms to new word pairs (Y–Z) were subtracted from the proportions of old responses to the three other types of word pairs to take into account the possibility of differing response bias for the three groups (see Jones & Jacoby, 2001, for a similar procedure). The data presented in Figures 1 and 2 are referred to as corrected recognition scores. Performance on the digit-monitoring task for participants in the divided-attention condition was measured in terms of the proportion of target sequences correctly identified. The mean number of target sequences to which the participants were exposed was 18.3, and the mean proportion of correctly identified sequences was .81 (SD = .15).

Word-pair recognition. In the word-pair recognition test, old responses to previously seen word pairs were considered hits, whereas old responses to the three other types of word pairs (conjunction, item, and new word pairs) constituted three types of false alarms. Table 1 shows that the distribution of old responses to the four types of word pairs followed a similar pattern to that observed in other studies using a similar paradigm (Kroll et al., 1996; Reinitz et al., 1994; Rubin et al., 1999). Table 1 shows that both older adults and younger adults under divided-attention conditions during encoding were more likely to make false alarms to conjunction word pairs, relative to full-attention younger adults. However, it also appears that older adults made more false alarms

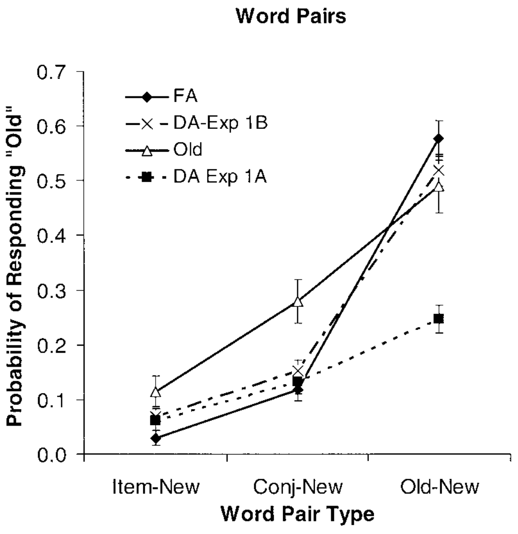

Figure 1. Proportion of "old" responses to old, conjunction (Conj), and item word pairs minus the proportion of "old" responses to new word pairs in the word-pair recognition test for Experiments (Exp) 1A and 1B. Old responses to old word pairs are considered hits, whereas old responses to conjunction word pairs and item word pairs are considered false alarms. Error bars denote standard errors of the means. FA = full attention; DA = divided attention.

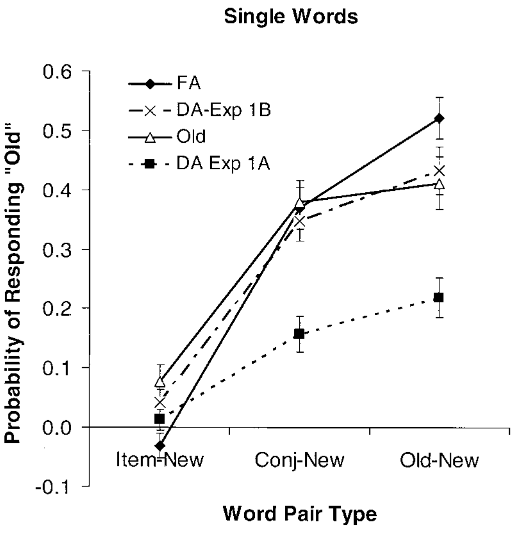

Figure 2. Proportion of "old" responses to old, conjunction (Conj), and item word pairs minus the proportion of "old" responses to new word pairs in the single-word recognition test for Experiments (Exp) 1A and 1B. Old responses to old word pairs and conjunction word pairs are considered hits, whereas old responses to item word pairs are considered false alarms. Error bars denote standard errors of the means. FA = full attention; DA = divided attention.

to the conjunction word pairs than did the divided-attention younger adults, suggesting differences in performance between these two groups.

The corrected recognition scores plotted in Figure 1 show that the older adult group still made more false alarms than the other two groups, despite the subtraction of "new" false alarms. It is not surprising that the full-attention younger adults made the fewest false alarms yet had the highest hit rate on old (A–B) pairs. We conducted a 3 (group) × 3 (word-pair type) analysis of variance (ANOVA) on the data shown in Figure 1 and found a significant main effect for word-pair type, $F(2, 186) = 190.1$, $p < .0001$, and group, $F(2, 93) = 12.4$, $p < .0001$. The interaction was also significant, $F(4, 186) = 20.1$, $p < .0001$. To compare the gradient of responses for older adults and for divided-attention younger adults, we conducted a 2 (group) × 3 (word-pair type) ANOVA. We found a significant main effect for word-pair type, $F(2, 124) = 67.6$, $p < .0001$, and group, $F(1, 62) = 19.1$, $p < .001$, as well as a significant interaction between word-pair type and group, $F(2, 124) = 8.0$, $p < .01$. To examine the use of associative information in recognition performance, we carried out a further 2 (group: older adults and divided-attention younger adults) × 2 (word-pair type: old–new and conjunction–new) ANOVA to see if an interaction was present. There were significant main effects of word-pair type, $F(1, 62) = 40.3$, $p < .0001$, and group, $F(1, 62) = 21.9$, $p < .0001$, as well as a just-significant interaction between word-pair type and group, $F(1, 62) = 4.0$, $p = .05$. These findings support the conclusion that younger adults whose attention was divided at encoding and older adults showed a different pattern of results on this test of associative information, but it should be noted that older participants had a greater tendency to respond positively to both old and conjunction pairs.

Single-word recognition. In the single-word recognition test, old responses to word pairs in which the second word had been previously presented were considered hits (old word pairs and conjunction word pairs), whereas old responses to the two other types of word pairs (item and new word pairs) constituted two types of false alarms. Again, we analyzed the results from the single-word recognition test by taking into account the different false-alarm rates to the new words for the three groups of participants. False alarms to new word pairs were subtracted from the proportion of old responses to the three other types of word pairs; the results are plotted in Figure 2. We conducted a 3 (group) × 3 (word-pair type) ANOVA and found significant main effects for word-pair type, $F(2, 186) = 212.0$, $p < .00001$, and group, $F(2, 93) = 11.8$, $p < .001$. The interaction was also significant, $F(4, 186) = 17.4$, $p < .00001$. To compare the performance of divided-attention younger adults and older adults on the two types of word pairs that constituted hits, we conducted a 2 (group: older adults and divided-attention younger adults) × 2 (word-pair type: conjunction and old) ANOVA. In this case, the main effect for group was significant, $F(1, 62) = 17.8$, $p < .001$, as was the main effect for word-pair type, $F(1, 62) = 7.0$, $p < .05$, but there was no significant interaction ($F < 1$). This result shows that the older adults performed somewhat better than the divided-attention younger adults and that both groups used context information to some degree, but there was no differential benefit for either group. In contrast, the younger adults who encoded the pairs under full attention showed a marked improvement in hit rates from conjunction to old. To further illustrate this result, a measure of the utilization of context information was derived by subtracting the probability of responding "old" to a word in a conjunction word pair (context absent) from the probability of responding "old" to a word in an old word pair (context present). This measure led to a "context utilization score" of .15 for the full-attention group, .05 for the divided-attention group, and .03 for the older adults. These scores were entered in a one-way ANOVA with the context utilization score as the dependent measure, and a significant between-groups effect was found, $F(2, 95) = 5.2$, $p < .01$. Follow-up post hoc tests (least significant difference) revealed that the older adults and the divided-attention group did not differ significantly from one another ($p > .50$), but both groups differed from the full-attention group ($p < .05$).

Previous researchers have suggested various reasons for the beneficial effects on recognition of maintaining the original pairing. The encoding specificity hypothesis put forward by Tulving and Thomson (1973) suggests that a word is encoded with a specific nuance of meaning when it is presented in the context of a paired word (e.g., *whiskey–WATER*) and that the word is less likely to be recognized at test if the paired word is changed (e.g., *lake–WATER*), essentially because its subtle meaning has been changed. This type of explanation was also offered by Light and Carter-Sobell (1970). Humphreys (1976, 1978) took a different approach, suggesting that recognition of the second word in a pair depends on two types of information, item and relational, and that the benefit of the relational information is lost if the word is presented in a new pairing at test. The present finding that neither older adults nor divided-attention younger adults showed much benefit of A–B over A–D test presentations can thus be construed either as their inability to use relational information or as their relative indifference to changes in the subtle encoded meaning of the second word. This processing inefficiency on the part of the older participants and the divided-attention younger participants is presumably attributable partly to poorer encoding of the second word in its specific context and partly to less efficient use of contextual and relational information at the time of retrieval. In this instance, division of attention and aging have the same effects.

Discriminability analysis. With respect to the question of whether the increasing similarity of lures to targets (Y–Z vs. A–X vs. A–D) would have differential effects on the groups' liability to make false-alarm responses, Figure 3 shows the difference scores for word-pair recognition between old pairs and new, item, and conjunction pairs, respectively. That is, Figure 3 plots the three groups' ability to discriminate presented word pairs (A–B) from three types of lures of increasing similarity to presented pairs (i.e., Y–Z, A–X, and A–D, respectively). Figure 3 shows that the ability to discriminate targets from lures declined for all three groups from new to conjunction pairs; it also shows (in line with the previous discussion) that the older adults and the divided-attention younger adults discriminated less well than the full-attention younger adults. Of greatest interest, Figure 3 shows that the decline in discriminability for the divided-attention younger adults was parallel to that of the full-attention younger adults but that the decline for the older adults was steeper. Increasing similarity of lures had a larger negative effect on discriminability for older adults than for either group of younger adults. This observation was demonstrated by the results of a 3 (group) × 3 (word-pair type) ANOVA on the data shown in Figure 3. The effect of group was significant, $F(2, 94) = 27.6$, $p < .0001$, as was the effect of

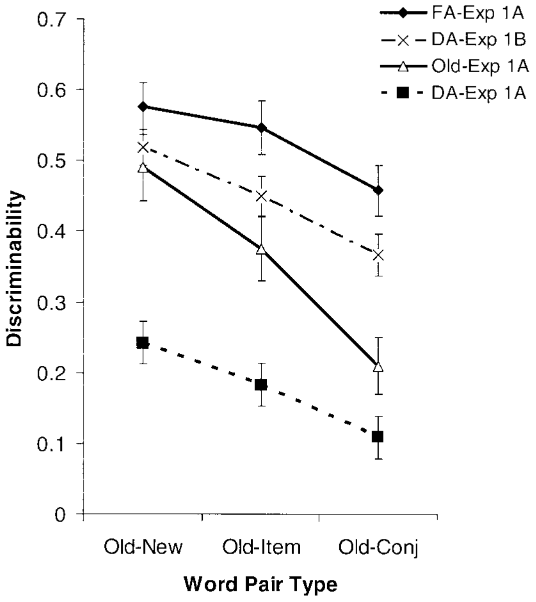

Figure 3. The difference in the proportion of "old" responses in the word-pair recognition test between old word pairs and new, item, and conjunction (Conj) word pairs in terms of the ability to discriminate presented word pairs from three types of lures in Experiments (Exp) 1A and 1B. Error bars denote standard errors of the means. FA = full attention; DA = divided attention.

word-pair type, $F(2, 188) = 78.1$, $p < .0001$. The interaction between group and word-pair type was also significant, $F(4, 188) = 6.8$, $p < .0001$. Subsequent 2 × 3 ANOVAs involving pairs of groups (both younger groups, older group and divided-attention younger group, and older group and full-attention younger group) revealed a significant interaction between group and word pair for the comparison between the divided-attention younger group and the older group, $F(1, 124) = 7.5$, $p < .001$, and for the comparison between the full-attention younger group and the older group, $F(1, 124) = 53.7$, $p < .0001$, but not for the comparison between both younger groups ($F < 1$).

Comparing item and associative deficits. The experiment yielded various possible measures of memory for item information, but perhaps the most representative is the subtraction of new pairs (Y–Z) from conjunction pairs (A–D) in the single-word recognition test. That is, yes responses to Y–Z pairs were treated as false alarms, and correct yes responses to A–D pairs were taken to measure hit rates. It is possible to take old pairs (A–B) as a measure of hit rate, but Figure 2 makes it clear that only the younger adults working under full attention profited significantly from the reinstatement of the original pair context in the A–B condition. It is also possible to take A–X pairs as a measure of false alarms, but given the older adults' high false-alarm rate on such pairs (.30), we concluded that this measure would yield a misleadingly low estimate of item information for the older adults. The measure of the deficit in item information from the level achieved by the younger adult group was thus given by the differences between full-attention younger adults on the one hand and older adults and divided-attention younger adults on the other hand. These differences are depicted in the conjunction minus new condition of Figure 2 and were −.01 and .21 for the older adults and the divided-attention younger adults, respectively.

The measure of associative information was taken to be the difference between old and conjunction word pairs in the word-pair recognition test. For other contrasts (e.g., between old pairs, A–B, and new pairs, Y–Z), the decision could be made on the basis of item information. That is, the participant was asked to judge if that exact word pair had been seen in the presentation list and so could respond "no" if he or she detected one or more completely new items. The measure of the deficit in associative information from the level achieved by the younger adult group was thus depicted by the differences between the full-attention younger group and the other two groups for the old minus conjunction condition shown in Figure 3. These differences were .24 for the older adults and .34 for the divided-attention younger adults.

To obtain distributions of deficit scores for the older adults and the divided-attention younger adults, each person's score for item information and associative information was subtracted from the mean of the young adults' (full-attention) scores for the relevant condition. A 2 × 2 ANOVA on these scores showed a significant effect of type of information, $F(1, 62) = 65.9$, $p < .0001$; a significant effect of group, $F(1, 62) = 14.9$, $p < .0001$; and, most important in terms of theoretical interest, a significant interaction between group and type of information, $F(1, 62) = 6.0$, $p < .05$. That is, both groups showed a greater deficit in associative information than in item information, and the two groups differed in the amount of deficit shown. The observation of a relatively greater deficit in associative information in the group of older adults is in line with the previous work reported by Naveh-Benjamin and Guez (2002) and Naveh-Benjamin et al. (2001), in which older adults showed a relatively greater deficit in associative information as compared with divided-attention younger adults. The present results differ from those of Naveh-Benjamin and colleagues, however, in that the divided-attention younger group also showed a greater deficit in associative than in item information (.34 vs. .21, respectively). This difference was statistically reliable, $t(31) = 4.66$, $p < .001$. Our findings thus differ from those of Naveh-Benjamin and colleagues in that both divided attention and aging were associated with greater deficits in associative than in item information, but the two sets of findings agree that aging is associated with a differentially greater negative effect on the recognition of associative information.

Experiment 1B

The results from Experiment 1A show some interesting similarities and differences between older adults and younger adults who studied word pairs under divided attention. However, there are two important issues to address before definitive conclusions can be drawn. First, if divided attention mimics aging because both cases involve a reduction in processing resources relative to younger adults, it may be important to bear in mind that attention was divided at encoding only in Experiment 1A, whereas processing resources are supposedly reduced at all times in older adults—during both encoding and retrieval. Thus, to serve as an accurate model of aging, it may be more appropriate to have the divided-attention group engage in the secondary task both at encoding and at retrieval. Second, it is evident from the memory performance of the divided-attention group that the secondary task used in Experiment 1A was very demanding, resulting in much poorer memory performance overall relative to the older adults. It would be preferable to have the divided-attention younger group and the older group performing equivalently to rule out the possibility of differential effects on item and associative information simply as a function of performance level. To address this issue, we chose an easier divided-attention task (identifying the digit 9 in a string of auditorily presented random digits) that participants performed during both encoding and retrieval. Pilot testing showed that this task should yield performance levels close to those shown by older adults in Experiment 1A. Other than these two modifications, the paradigm was exactly the same as that used in Experiment 1A.

Method

Participants. Thirty-two undergraduate students from the University of Toronto (27 women and 5 men, mean age = 20.1 years, mean number of years of education = 14.1) volunteered to participate and received course credit for their participation. All participants were in the divided-attention condition—the only condition in the present study.

Materials and procedure. The materials and procedure were identical to those used in Experiment 1A; the only exception was the modified secondary task, which participants performed at both encoding and retrieval. The digit-monitoring task consisted of an auditory presentation of single digits ranging from 0 to 9 in a random order. Twelve hundred digits were spoken by a female voice and recorded on a tape recorder at a rate of 1 digit every 1.5 s, producing a 30-min recording. The participant's task was to monitor the series of digits for targets, defined as the digit 9, and to report the digit's occurrence by repeating it aloud. Digits occurred in a random order, and the lags between target digits ranged from 2 to 16 digits, with a mean lag of 7.2 digits. Performance on the task was monitored by the experimenter.

Results and Discussion

The results for the word-pair recognition test and for the single-word recognition tests are shown in Table 1. The corrected recognition scores are displayed in Figures 1 and 2 for word-pair and single-word tests, respectively, to allow for a direct comparison with the groups in Experiment 1A. Performance on the digit-monitoring task was measured in terms of the proportion of target digits correctly identified. The mean number of targets to which the participants were exposed in total was 58.7 (encoding and recognition), and the mean proportion of correctly identified targets was .94 during the encoding phase, .85 during the word-pair recognition test, and .84 during the single-word recognition test.

Word-pair recognition. The main contrast of interest is between the present divided-attention younger group and the older group from Experiment 1A. Therefore, we conducted a 2 (group) × 3 (word-pair type) ANOVA on the corrected recognition scores shown in Figure 1. This analysis revealed an effect of word-pair type, $F(2, 124) = 143.4$, $p < .001$, no main effect of group, $F(1, 62) = 2.2$, $p > .05$, but a significant interaction, $F(2, 124) = 5.0$, $p < .01$. This last effect reflects the fact that hit rates were approximately equivalent between the groups but that the older participants made more false alarms. A further analysis between the same groups but including only the old minus new and conjunction minus new scores showed a significant main effect for word-pair type, $F(1, 62) = 117.1$, $p < .0001$, but not for group ($F < 1.6$, $p = .22$). Of greatest interest in terms of the purpose of this study, the interaction was significant, $F(1, 62) = 8.8$, $p < .01$, indicating that the older adults were more likely to generate false alarms to the conjunction word pairs.

Single-word recognition. Again, the pattern of data shown in Table 1 for the present divided-attention group was similar to that of the previous divided-attention group but showed much higher levels of performance. To compare how the present divided-attention group performed relative to the older adults from Experiment 1A, we conducted a 2 (group) × 3 (word-pair type) ANOVA by using the corrected recognition scores shown in Figure 2. In this case, there was a significant main effect of word-pair type, $F(2, 124) = 126.2$, $p < .0001$, but no main effect of group ($F < 1$) and no significant interaction ($F < 1$). Because there was no main effect of group, it appears that the choice of a less demanding secondary task successfully brought the memory performance of the divided-attention group to a more suitable and comparable level to that of the older adults, relative to the overall poor performance of the divided-attention group in Experiment 1A.

In terms of the context utilization score that we mentioned previously (derived by subtracting "old" responses to conjunction pairs from "old" responses to old pairs in the single-word recognition test), the divided-attention group in the present study displayed a score of .09. This score suggests that the context provided by the first word (in old word pairs) was somewhat useful when the participants were attempting to recognize the second word, and this score was greater than those shown by both the divided-attention group and the older adults in Experiment 1A, likely due to the less demanding secondary task in the present experiment. When deficits in performance were measured relative to the levels shown by the full-attention younger group in Experiment 1A, these values were .03 for item recognition and .09 for associative recognition. The greater drop in associative information was only marginally significant, $t(31) = 1.87$, $p = .07$, although it was in the same direction as the results from Experiment 1A. Both deficits were small, again due to the much easier secondary task.

Discriminability analysis. With respect to the question of whether the increasing similarity of lures (Y–Z vs. A–X vs. A–D) would have differential effects on the groups' liability to make false-alarm responses, Figure 3 shows the difference scores for word-pair recognition between old pairs and new, item, and conjunction pairs, respectively. It is evident from Figure 3 that the decline in discriminability for the divided-attention group in the present study was parallel to that of the full-attention younger group and that of the divided-attention younger group from Experiment 1A, but again the decline for older adults was steeper. Of greatest interest is the comparison between the divided-attention group from the present study and the older adults from Experiment 1A. A 2 (group) × 3 (word-pair type) ANOVA showed a significant main effect for word-pair type, $F(2, 124) = 62.3$, $p < .0001$, but only a marginal effect for group, $F(1, 62) = 3.0$, $p < .09$. Of most importance, the interaction between group and word-pair type was significant, $F(2, 124) = 5.9$, $p < .01$. Thus, as shown in the previous study, increasing similarity of lures had a larger negative effect on discriminability for older adults than for younger adults working under divided-attention conditions.

Experiment 2A

Experiment 1 showed that there were not only similarities between the effects of aging and divided attention on memory for item and associative information but also some marked differences between the two variables. In the first category, both aging and divided attention reduced performance relative to the levels shown by younger adults, and both groups showed a reduced benefit associated with context reinstatement (A–B vs. A–D pairs) in the item recognition paradigm. In contrast, whereas the effect of divided attention was primarily seen as a reduction in hit rates with relatively small increases in false-alarm rates, the effect of aging was seen most dramatically in the older group's greatly increased false-alarm rates in pair recognition, especially when lures were most similar to targets (see Table 1 and Figures 1 and 3). Second, when pair recognition scores were plotted as ability to discriminate between distractor pairs and targets (Figure 3), the divided-attention groups' functions were parallel to the function associated with the full-attention younger group, but the older adults' function was steeper, reflecting their particular difficulty in discriminating A–D from A–B pairs. Finally, the analyses of deficits in item and associative information relative to the full-attention younger group found that the older adults showed differentially greater deficits in associative information than in item information. These findings are in line with the evidence presented by Naveh-Benjamin and Guez (2002) and Naveh-Benjamin et al. (2001) and with the associative deficit hypothesis of aging (Naveh-Benjamin, 2000). However, the findings are not in line with the suggestions by Craik (1982, 1983; Craik & Byrd, 1982) that the effects of aging can be mimicked in all respects by division of attention. Therefore, we considered it important to replicate the main findings of Experiment 1 by using a slightly different design before formulating a changed or an amended position.

In Experiment 2A, we tested young adults only and used a within-subject design. Each person participated in three consecutive blocks: (a) full attention at both encoding and recognition, (b) divided attention at encoding and full attention at recognition, and (c) divided attention at both encoding and recognition. Given that the main results of interest from Experiment 1 concerned associative information, participants were given only the word-pair recognition test in each block. We also introduced a secondary task that was slightly less demanding than the one used in Experiment 1A but slightly more demanding than the one used in Experiment 1B. The task in the present study involved identifying two consecutive odd digits from a continuous auditory stream of digits. To round out the design, we tested a group of older adults and an additional group of younger adults working under full-attention conditions in all three blocks; the design and results are presented as Experiment 2B.

Method

Participants. Twenty-seven undergraduate students from the University of Toronto (19 women and 8 men, mean age = 19.3 years, mean number of years of education = 14.2) volunteered to participate and received course credit for their participation. All volunteers participated in each of the three blocks.

Materials. The materials were identical to those used in Experiment 1A, with the exceptions that a modified secondary task was used, study and recognition lists were somewhat shorter, and only the associative recognition test was given after each study phase. The digit-monitoring task consisted of an auditory presentation of single digits ranging from 0 to 9 in a random order. Twelve hundred digits were spoken by a female voice and recorded on a tape recorder at a rate of 1 digit every 1.5 s, producing a 30-min recording. The participant's task was to monitor the series of digits for targets, to listen for the presence of 2 consecutive odd digits, and to report the presence of these digits to the experimenter by repeating them aloud. The digits occurred in a random order, and the lags between target digit sequences ranged from 4 to 15 digits, with a mean lag of 9.6 digits.

Procedure and design. The procedure was similar to that used in the previous experiments, except for the within-subject design, the modified secondary task, and slightly shorter list lengths for each block. The order of the blocks was counterbalanced across participants such that each block occurred in each of the three positions an equal number of times. Each study phase consisted of 45 original word pairs (none of the words were repeated in a subsequent study phase for the participant), and each recognition test consisted of 60 word pairs (15 of each type: old, conjunction, item, and new). Participants were given instructions regarding the study and the presence or absence of the secondary task prior to the beginning of each block.

Results and Discussion

The results of the word-pair recognition test for each condition are displayed in Table 2. The corrected recognition scores are displayed in Figure 4. Performance on the digit-monitoring task was measured in terms of the proportion of target sequences correctly identified. The mean number of target sequences to which the participants were exposed in each block was 7.8 during encoding and 8.9 during recognition. The mean proportion of correctly identified sequences was .81 for divided attention at encoding only, .85 during the encoding phase of the divided attention at encoding and recognition condition, and .55 during the recognition phase of this last-named condition. The finding of poorer secondary task performance at retrieval than at encoding is consistent with results from other studies (e.g., Craik et al., 1996).

Word-pair recognition. The corrected recognition scores are shown in Figure 4. The pattern of results replicated the pattern for the corresponding conditions in Experiment 1A; that is, the participants in the full-attention condition made few false alarms on the item minus new and conjunction minus new conditions and achieved a substantial hit rate on the old minus new condition. The two divided-attention younger adult conditions yielded almost

Table 2
Mean Proportion of "Old" Responses to Each of the Four Word-Pair Types in the Word-Pair Recognition Test in the Three Blocks of Experiment 2A and for the Two Groups in Experiment 2B

	Word-pair type			
Experiment and group	Old	Conj	Item	New
Experiment 2A				
Full attention	.75 (.04)	.12 (.02)	.04 (.01)	.03 (.01)
Divided attention (Encoding only)	.42 (.04)	.20 (.03)	.11 (.02)	.05 (.01)
Divided attention (Encoding and retrieval)	.45 (.04)	.20 (.04)	.12 (.03)	.07 (.02)
Experiment 2B				
Full attention	.83 (.02)	.08 (.01)	.02 (.01)	.01 (.01)
Older	.70 (.03)	.42 (.04)	.18 (.02)	.10 (.02)

Note. Hits constitute "old" responses to old word pairs. Standard errors of the means are in parentheses. Conj = conjunction.

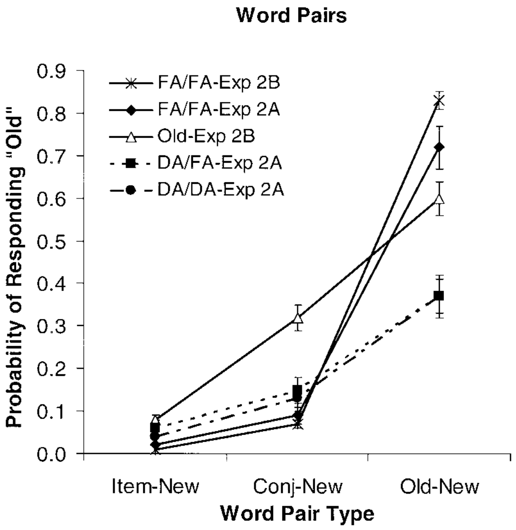

Figure 4. Proportion of "old" responses to old, conjunction (Conj), and item word pairs minus the proportion of "old" responses to new word pairs in the word-pair recognition test for Experiments (Exp) 2A and 2B. Old responses to old word pairs are considered hits, whereas old responses to conjunction word pairs and item word pairs are considered false alarms. DA/DA refers to divided attention at encoding (during the study phase) as well as divided attention at retrieval (during the recognition test), DA/FA refers to divided attention at encoding but full attention at retrieval, and FA/FA refers to full attention at both encoding and retrieval. Error bars denote standard errors of the means.

identical results, so dividing attention at retrieval as well as at encoding made very little difference. Both divided-attention conditions showed substantially lower hit rates than the full-attention condition but very little increase in false-alarm rates. These observations were demonstrated by the results of a 3 (attention condition) × 3 (word-pair type) ANOVA on the data shown in Figure 4. The analysis yielded significant effects of attention condition, $F(2, 78) = 6.5$, $p = .002$; of word-pair type, $F(2, 156) = 177.8$, $p < .001$; and of the interaction, $F(4, 156) = 17.4$, $p < .001$. A similar analysis carried out to compare the two divided-attention conditions yielded a significant effect of word-pair type, $F(2, 104) = 59.1$, $p < .001$, but no main effect of condition and no interaction (both *F*s < 1).

Discriminability analysis. To examine whether the increasing similarity of lures (Y–Z vs. A–X vs. A–D) had differential effects on false-alarm responses in the various conditions, Figure 5 shows the difference scores for word-pair recognition between old pairs and new, item, and conjunction pairs. This analysis allowed for a comparison of the pattern of results with the groups tested in the previous experiments; the main point to observe in Figure 5 is that all three conditions of Experiment 2A showed parallel effects with respect to word-pair type. A 3 (condition) × 3 (word-pair type) ANOVA showed a significant main effect of word-pair type, $F(2, 156) = 42.8$, $p < .0001$, and condition, $F(2, 78) = 21.2$, $p < .0001$. Of greatest importance, the interaction between condition and word-pair type was not significant ($F < 1$). As in Experiment 1 then, the effect of divided attention was to reduce discriminability, but not differentially as a function of word-pair type. The next comparison of interest was how older adults performed in terms of discriminability. To provide a group of older adults who participated under similar conditions, we conducted Experiment 2B, and the relevant discriminability analysis is presented in the following results section.

Experiment 2B

To provide an appropriate comparison with the divided-attention conditions (i.e., a within-subject design) of Experiment 2A, we tested a group of older adults in a design similar to that of Experiment 2A but under full-attention conditions. Furthermore, an additional group of young adults was tested under the same full-attention conditions. Specifically, both the younger adults and the older adults in the present experiment participated in three identical blocks (each block consisted of encoding under full attention and an associative recognition test under full attention) in order to compare their performance with that of the participants in Experiment 2A.

Method

Participants. Twenty undergraduate students from the University of Toronto (15 women and 5 men, mean age = 22.7 years, mean number of years of education = 16.0) volunteered to participate and received course credit for their participation. Twenty older adults (8 women and 12 men, mean age = 71.2 years, mean number of years of education = 14.6) also participated in the study and were paid $10 (Canadian funds; approximately U.S. $7.40) for their participation.

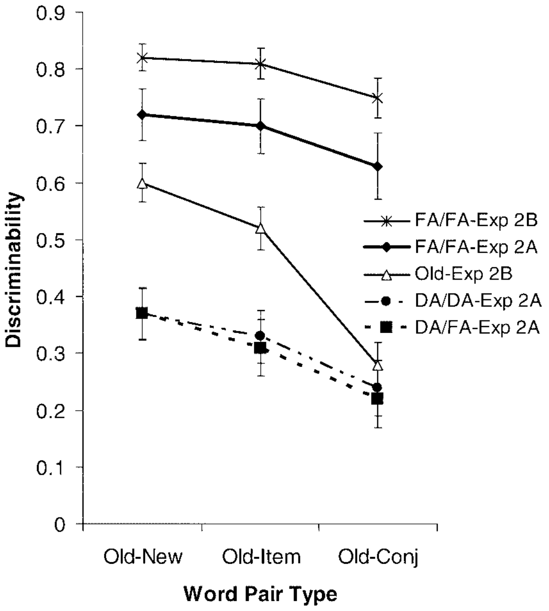

Figure 5. The difference in the proportion of "old" responses in the word-pair recognition test between old word pairs and new, item, and conjunction (Conj) word pairs in terms of the ability to discriminate presented word pairs from three types of lures in Experiments (Exp) 2A and 2B. DA/DA refers to divided attention at encoding (during the study phase) as well as divided attention at retrieval (during the recognition test), DA/FA refers to divided attention at encoding but full attention at retrieval, and FA/FA refers to full attention at both encoding and retrieval. Error bars denote standard errors of the means.

Materials and procedure. The materials and procedure were identical to those used in Experiment 2A, with the exception that each block was completed under full attention for both the younger and the older adults. All participants were tested on all three blocks.

Results and Discussion

Word-pair recognition. The results for word-pair recognition performance for both groups are displayed in Table 2. The corrected recognition scores are shown in Figure 4. Because the purpose of including these two groups was to compare their performance with that of the divided-attention groups in Experiment 2A, we carried out specific ANOVAs. To compare performance between the divided-attention conditions at both encoding and recognition from Experiment 2A with performance of the older adults in the present study, we conducted a 2 (group) × 3 (word-pair-type corrected scores) ANOVA. There were significant main effects of word-pair type, $F(2, 104) = 122.6$, $p < .0001$, and group, $F(1, 52) = 33.5$, $p < .0001$, as well as a significant interaction between word-pair type and group, $F(2, 104) = 6.8$, $p < .0001$. From Figure 4, one can see that the interaction reflected similar false-alarm rates between the groups for item minus new pairs but greater probabilities of “old” responses in the older adult group for both conjunction minus new pairs (false alarms) and old minus new pairs (hits). A closer examination of memory for associative information involves comparing “old” responses to the old and conjunction word pairs. A 2 (group) × 2 (word-pair type: old and conjunction corrected recognition scores) ANOVA showed significant main effects for word-pair type, $F(1, 52) = 68.9$, $p < .0001$, and group, $F(1, 52) = 33.2$, $p < .0001$, but no interaction ($F < 1$).

Discriminability analysis. As in the previous studies, difference scores for word-pair recognition between old pairs and new, item, and conjunction pairs are presented in Figure 5 and provide a measure of discriminability. The purpose of the present experiment was to see how older adults compared with the younger adults from Experiment 2A, especially in the condition in which attention was divided at both encoding and retrieval. A 2 (group: older adults and younger adults under divided attention at both encoding and retrieval) × 3 (word-pair type: old minus new, old minus item, and old minus conjunction) ANOVA showed a significant main effect of word-pair type, $F(2, 104) = 93.1$, $p < .0001$, and group, $F(1, 52) = 7.6$, $p < .01$. A significant interaction between group and word-pair type was also present, $F(2, 104) = 17.0$, $p < .0001$. Thus, as shown in Experiment 1, increasing similarity of lures had a larger negative effect on discriminability for older adults than for younger adults whose attention was divided at both encoding and retrieval.

General Discussion

The major goal of this study was to compare the effects of normal aging with those of divided attention on memory for item and associative information. The results showed that older adults and divided-attention younger adults performed very similarly on single-word recognition tests tapping item information when the difficulty of the secondary task was adjusted to give comparable levels of performance. However, the two groups performed very differently relative to full-attention younger controls on word-pair tests. Specifically, the divided-attention younger groups showed substantial reductions in hit rates but very slight increases in false-alarm rates relative to the full-attention younger groups. In contrast, the two groups of older adults showed comparatively small reductions in hit rates but a substantial increase in false-alarm rates, especially on the recombined (A–D) distractor items, relative to younger controls. In summary, the salient characteristic of younger adults performing under divided-attention conditions in this paradigm was a reduction in hit rates, whereas the salient characteristic of older adults was an increase in false alarms to similar distractors.

The deficit in item information was measured in the single-word recognition test by taking the difference between the younger adults’ score in the conjunction minus new condition (see Figure 2) and the corresponding scores of the older adults and the divided-attention younger adults. The deficit in associative information was taken from the word-pair recognition test as the difference between the younger adults’ scores and the scores of the other groups on the old minus conjunction condition shown in Figures 3 and 5. As reported in the results sections, these comparisons showed that the deficit was greater in associative information than in item information and that the deficit in associative information was greater for the older adults relative to various groups of divided-attention younger adults. These findings are in concert with those of Naveh-Benjamin (2001; Naveh-Benjamin & Guez, 2002) and provide further evidence for the associative deficit hypothesis. However, our results differ from those of Naveh-Benjamin and his colleagues in that divided attention (like aging) had greater negative effects on associative information than on item information. According to our results then, the associative deficit hypothesis is not uniquely relevant to aging. We speculate that it may apply to all conditions involving a reduction in processing resources.

Other findings that are worth noting include the observation in the single-word paradigm that whereas younger adults working under full-attention conditions showed an increase in hit rates (presumably due to reinstatement of original context) from conjunction to old pairs, neither older adults nor divided-attention younger adults showed the same amount of increase (see Figure 2). In this instance, the divided-attention younger group showed the same pattern of responding as the older group, but in the discriminability analyses shown in Figures 3 and 5, the groups performed differently. Figures 3 and 5 show strikingly similar patterns; discriminability decreased as the lures became more similar to the target pairs, and the decreases were sharper for older adults than for younger adults working under either full or divided attention. These latter two groups showed parallel decreases. The discriminability results thus again make the point that older adults differed from divided-attention younger adults in their lessened ability to discriminate targets from similar lures in the associative recognition paradigm. In particular, older adults showed a greatly increased tendency to make false-alarm responses to conjunction pairs.

One final analysis also demonstrated this difference between the divided-attention younger adults and the older adults. Figure 6 shows associative discriminability (defined as corrected old minus corrected conjunction scores in the word-pair paradigm) plotted against corrected hit rate (old minus new) for all nine groups or conditions examined in the study. Figure 6 shows that all seven

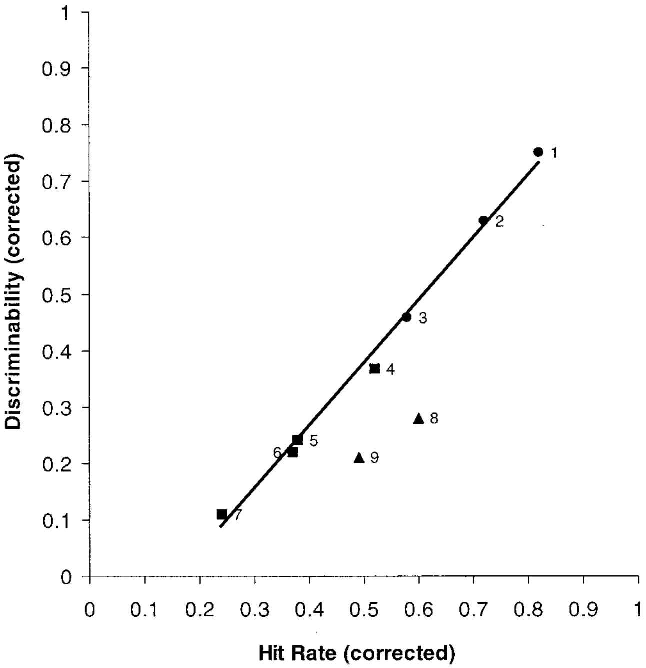

Figure 6. Discriminability (derived from the corrected "old" responses to old word pairs minus "old" responses to conjunction word pairs in the word-pair recognition test) as a function of corrected hit rate (hits minus respective false alarms to new word pairs) for each group in the word-pair recognition test in all experiments. Points 1–3 (circles) refer to full-attention younger groups (1 = young, full attention, Experiment 2B; 2 = young, full attention/full attention [full attention at both encoding and retrieval], Experiment 2A; 3 = young, full attention, Experiment 1A). Points 4–7 (squares) refer to divided-attention younger groups (4 = young, divided attention, Experiment 1B; 5 = young, divided attention/divided attention [divided attention at both encoding and retrieval], Experiment 2A; 6 = young, divided attention/full attention [divided attention at encoding but full attention at retrieval], Experiment 2A; 7 = young, divided attention, Experiment 1A). Points 8 and 9 (triangles) refer to older adults (8 = old, Experiment 2B; 9 = old, Experiment 1A). The regression line for Points 1–7 is shown and is described by the equation $y = 1.123x - 0.186$, $R^2 = .99$. Please see the General Discussion section of the text for more details.

younger groups or conditions were well fitted by one linear function ($R^2 = .99$) but that the two older groups clearly deviated from the function. Because discriminability is calculated as hits minus false alarms, graphing discriminability against hits is essentially one way to show the relation between hits and false alarms in associative recognition. The fact that one linear function fit all of the conditions involving younger adults, including the divided-attention conditions, means that false-alarm rates (conjunction minus new) remained relatively constant across all conditions despite large variations in hit rate. In fact, corrected hit rates for the young conditions ranged from .24 to .82, whereas corrected false-alarm rates ranged only from .07 to .16. The mean of the seven false-alarm rates associated with younger participants was .12, with a standard deviation of .03; the corresponding mean for the two groups of older participants was .30, some 6 standard deviations above the younger participants' mean value. The theoretical implication of these results is that different levels of difficulty and different degrees of divided attention in younger adults resulted in large changes in hit rates but in comparatively small changes in false alarms, measured here as "old" responses to conjunction pairs. In contrast, the groups of older adults in the present study made many more conjunction errors than did their younger counterparts.

Jacoby and colleagues (e.g., Jacoby et al., 1996; Jones & Jacoby, 2001; Jones et al., 2001) have argued that familiarity and recollection provide alternative bases for responding "old" in tests of recognition memory. Furthermore, in the context of a conjunction paradigm similar to the word-pair conditions in the present study, Jones and Jacoby (2001) suggested that conjunction errors reflect familiarity in the absence of recollection and that a decrease in hit rates without an alteration of false alarms (conjunction errors) can be interpreted as an effect on recollection but not on familiarity. In these terms, the divided-attention younger groups in the present study fit the second pattern, and thus divided attention at encoding may be considered to reduce recollection but leave familiarity unaltered (see also Reinitz et al., 1994). It seems likely that aging also decreases recollection; in the present study, the drops in corrected hit rates shown by the older groups relative to the relevant full-attention younger control groups were .09 in Experiment 1A and .22 in Experiment 2B. However, the more dramatic age-related difference was the increase in conjunction errors: .16 in Experiment 1A and .25 in Experiment 2B; in Jacoby et al.'s terms these age-related errors reflect an age-related increase in the dependence on familiarity, unopposed by the corrective influence of recollection. By this analysis, divided attention and aging are similar in that both are associated with a decline in recollection, but, in addition, aging is associated with a greater dependence on familiarity, leading older adults to make more false alarms to distractor items that are very similar to target items.

The mechanism (or mechanisms) underlying these impairments remains to be identified, but recent findings from neuropsychology and cognitive neuroimaging have provided some clues. For example, both normal aging and division of attention in young adults are associated with similar reductions in left prefrontal cortex activity (Cabeza et al., 1997; Grady et al., 1995; Iidaka, Anderson, Kapur, Cabeza, & Craik, 2000; Shallice et al., 1994). The hippocampal formation is also likely to be involved in the encoding and retrieval of associative information, and evidence supporting this point comes from studies by Kroll et al. (1996) and Reinitz et al. (1996), as well as from the theoretical analysis provided by Moscovitch and Winocur (1992; Moscovitch, 2000). However, it may be that whereas aging results in reduced efficiency of processing at the level of the hippocampus formation, younger adults under divided attention do not show this impairment (Naveh-Benjamin, 2001; Naveh-Benjamin et al., 2001). Thus, although frontal lobe functions may be taxed during divided attention, the hippocampus may not be involved in secondary task processing and thus allows younger adults to successfully process associative information in the memory task. Further research that uses a secondary task that involves processing associative information (or involves the hippocampus in some greater capacity) may show that situations of divided attention are more similar to aging under these conditions.

In conclusion, how do the present results fit with Craik's (1982, 1983) claim that the effects of aging can be mimicked by having younger adults perform under divided-attention conditions? We argue that aging and divided attention are similar in that both are associated with a reduction in available processing resources, which in turn is related to a decrease in recollection in memory tasks. The present results show that aging is associated with a second factor, however, that differentiates aging from divided attention—namely, a greatly increased liability to make false-alarm errors to similar distractors in the associative recognition paradigm. This age-related impairment presumably reflects some combination of an inefficiency in binding processes during encoding (e.g., Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000) and an undue reliance on familiarity at the time of retrieval (Jones & Jacoby, 2001). One possible account of the latter effect is that older adults fail to process distractor items sufficiently deeply during retrieval and thus respond "old" on the basis of relatively shallow information that is similar to that of target information, without accessing the deeper or more specific information (recollection) that would enable them to reject the distractors (see Jones & Jacoby, 2001, for a related discussion). Our findings are thus partly but not entirely in line with those reported by Naveh-Benjamin (e.g., Naveh-Benjamin & Guez, 2002; Naveh-Benjamin et al., 2001), and our conclusion is that divided attention resembles aging in some but not all respects. It seems likely, in fact, that a complete account of age-related memory loss will be multifactorial, reflecting inefficiencies in various types of processing as well as a reduction in attentional resources.

References

Anderson, J. R., & Bower, G. H. (1973). *Human associative memory.* Washington, DC: Winston.

Cabeza, R., Grady, C. L., Nyberg, L., McIntosh, A. R., Tulving, E., Kapur, S., et al. (1997). Age-related differences in neural activity during memory encoding and retrieval: A positron emission tomography study. *Journal of Neuroscience, 17,* 391–400.

Chalfonte, B. L., & Johnson, M. K. (1996). Feature memory and binding in young and older adults. *Memory & Cognition, 24,* 403–416.

Craik, F. I. M. (1982). Selective changes in encoding as a function of reduced processing capacity. In F. Klix, S. Hoffman, & E. Van der Meer (Eds.), *Cognitive research in psychology* (pp. 152–161). Berlin, Germany: Deutscher Verlag der Wissenschaften.

Craik, F. I. M. (1983). On the transfer of information from temporary to permanent memory. *Philosophical Transactions of the Royal Society of London, Series B, 302,* 341–359.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. E. Trehub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum Press.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General, 125,* 159–180.

Craik, F. I. M., & Simon, E. (1980). Age differences in memory: The role of attention and depth of processing. In L. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging* (pp. 95–112). Hillsdale, NJ: Erlbaum.

Grady, C. L., McIntosh, A. R., Horwitz, B., Maisog, J. M., Ungerleider, L. G., Mentis, M. J., et al. (1995, July 14). Age-related reductions in human recognition memory due to impaired encoding. *Science, 269,* 218–221.

Hockley, W. E., & Cristi, C. (1996). Tests of encoding tradeoffs between item and associative information. *Memory & Cognition, 24,* 202–216.

Humphreys, M. S. (1976). Relational information and the context effect in recognition memory. *Memory & Cognition, 4,* 221–232.

Humphreys, M. S. (1978). Item and relational information: A case for context independent retrieval. *Journal of Verbal Learning and Verbal Behavior, 17,* 175–187.

Iidaka, T., Anderson, N. D., Kapur, S., Cabeza, R., & Craik, F. I. M. (2000). The effect of divided attention on encoding and retrieval in episodic memory revealed by positron emission tomography. *Journal of Cognitive Neuroscience, 12,* 267–280.

Jacoby, L. L., Jennings, J. M., & Hay, J. F. (1996). Dissociating automatic and consciously controlled processes: Implications for diagnosis and rehabilitation of memory deficits. In D. Hermann, C. McEvoy, C. Hertzog, P. Hertel, & M. K. Johnson (Eds.), *Basic and applied memory research: Theory in context* (Vol. 1, pp. 161–193). Mahwah, NJ: Erlbaum.

Jones, T. C., & Jacoby, L. L. (2001). Feature and conjunction errors in recognition memory: Evidence for dual-processing theory. *Journal of Memory and Language, 45,* 82–102.

Jones, T. C., Jacoby, L. L., & Gellis, L. A. (2001). Cross-modal feature and conjunction errors in recognition memory. *Journal of Memory and Language, 44,* 131–152.

Kroll, N. E. A., Knight, R. T., Metcalfe, J., Wolf, E. S., & Tulving, E. (1996). Cohesion failure as a source of memory illusions. *Journal of Memory and Language, 35,* 176–196.

Light, L. L., & Carter-Sobell, L. (1970). Effects of changed semantic context on recognition memory. *Journal of Verbal Learning and Verbal Behavior, 9,* 1–11.

Light, L. L., Prull, M. W., La Voie, D. J., & Healy, M. R. (2000). Dual-process theories of memory in old age. In T. J. Perfect & E. A. Maylor (Eds.), *Models of cognitive aging* (pp. 238–300). Oxford, England: Oxford University Press.

McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology, 41,* 175–192.

Moscovitch, M. (2000). Theories of memory and consciousness. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 609–625). New York: Oxford University Press.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315–372). Hillsdale, NJ: Erlbaum.

Murdock, B. B., Jr. (1982). A theory for the storage and retrieval of item and associative information. *Psychological Review, 89,* 609–626.

Murdock, B. B., Jr. (1993). TODAM2: A model for the storage and retrieval of item, associative, and serial-order information. *Psychological Review, 100,* 183–203.

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1170–1187.

Naveh-Benjamin, M. (2001). The effects of divided attention on encoding processes: Underlying mechanisms. In M. Naveh-Benjamin, M. Moscovitch, & H. L. Roediger III (Eds.), *Perspectives on human memory and cognitive aging: Essays in honor of Fergus Craik* (pp. 193–207). Philadelphia: Psychology Press.

Naveh-Benjamin, M., & Guez, J. (2002, November). *Divided attention in young adults and adult age differences in episodic memory: A common associative deficit mechanism?* Paper presented at the 43rd Annual Meeting of the Psychonomic Society, Kansas City, MO.

Naveh-Benjamin, M., Guez, J., Givati, A., & Marom, M. (2001). *The effects of divided attention in young adults and adult age differences in episodic memory: A common associative deficit mechanism?* Manuscript submitted for publication.

Rabinowitz, J. C., Craik, F. I. M., & Ackerman, B. P. (1982). A processing resource account of age differences in recall. *Canadian Journal of Psychology, 36,* 325–344.

Reinitz, M. T., Lammers, W. J., & Cochran, B. P. (1992). Memory-conjunction errors: Miscombinations of stored stimulus features can produce illusions of memory. *Memory & Cognition, 20,* 1–11.

Reinitz, M. T., Morrissey, J., & Demb, J. (1994). Role of attention in face encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 161–168.

Reinitz, M. T., Verfaellie, M., & Milberg, W. P. (1996). Memory conjunction errors in normal and amnesic subjects. *Journal of Memory and Language, 35,* 286–299.

Rubin, S. R., Van Petten, C., Glisky, E. L., & Newberg, W. M. (1999). Memory conjunction errors in younger and older adults: Event-related potential and neuropsychological data. *Cognitive Neuropsychology, 16,* 459–488.

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

Schneider, W. (1990). Micro-Experimental Laboratory (Version 2.0) [Computer software]. Pittsburgh, PA: Psychology Software Tools.

Shallice, T., Fletcher, P., Frith, C. D., Grasby, P., Frackowiak, R. S. J., & Dolan, R. J. (1994). Brain regions associated with acquisition and retrieval of verbal episodic memory. *Nature, 368,* 633–635.

Spencer, W. D., & Raz, N. (1995). Differential age effects on memory for content and context: A meta-analysis. *Psychology and Aging, 10,* 527–539.

Troyer, A. K., & Craik, F. I. M. (2000). The effects of divided attention on memory for items and their context. *Canadian Journal of Experimental Psychology, 54,* 161–171.

Troyer, A. K., Winocur, G., Craik, F. I. M., & Moscovitch, M. (1999). Source memory and divided attention: Reciprocal costs to primary and secondary tasks. *Neuropsychology, 13,* 467–474.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352–373.

Received November 12, 2001
Revision received January 15, 2003
Accepted April 3, 2003 ■

New Editors Appointed, 2005–2010

The Publications and Communications Board of the American Psychological Association announces the appointment of two new editors for 6-year terms beginning in 2005:

- *Journal of Consulting and Clinical Psychology:* **Annette M. La Greca,** PhD, ABPP, Professor of Psychology and Pediatrics, Department of Psychology, P.O. Box 249229, University of Miami, Coral Gables, FL 33124-0751.
- *Developmental Psychology:* **Cynthia García Coll,** PhD, Brown University, 21 Manning Walk, Providence, RI 02912.

Electronic manuscript submission. As of January 1, 2004, manuscripts should be submitted electronically via the journal's Manuscript Submission Portal. Authors who are unable to do so should correspond with the editor's office about alternatives. Portals are available at the following addresses:

- For *Journal of Consulting and Clinical Psychology,* submit via www.apa.org/journals/ccp.html.
- For *Developmental Psychology,* submit via www.apa.org/journals/dev.html.

Manuscript submission patterns make the precise date of completion of the 2004 volumes uncertain. Current editors, Mark B. Sobell, PhD, and James L. Dannemiller, PhD, respectively, will receive and consider manuscripts through December 31, 2003. Should 2004 volumes be completed before that date, manuscripts will be redirected to the new editors for consideration in 2005 volumes.