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Associative Recognition in Alzheimer's Disease: Evidence for Impaired Recall-to-Reject

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Patients with mild Alzheimer's disease (AD) were compared with age-matched control subjects on an associative recognition task. Subjects studied pairs of unrelated words and were later asked to distinguish between these same studied pairs (intact) and new pairs that contained either rearranged studied words (rearranged) or nonstudied words (nonstudied). Studied pairs were presented either once or 3 times. Repetition increased hits to intact pairs in both groups, but repetition increased false alarms to rearranged pairs only in patients. This latter pattern indicates that repetition increased familiarity of the rearranged pairs, but only the control subjects were able to counter this familiarity by recalling the originally studied pairs (a recall-to-reject process). AD impaired this recall-to-reject process, leading to more familiarity-based false alarms. These data support the idea that recollection-based monitoring processes are impaired in mild AD.

Episodic memory is one of the first cognitive abilities that is impaired by Alzheimer's disease (AD; see Hodges, 2000, for an overview). This memory impairment is characterized by decreases in accurate recall and recognition and, in some cases, by increases in recall intrusions and recognition false alarms (e.g., Budson, Daffner, Desikan, & Schacter, 2000; Dalla Barba & Wong, 1995). Increased instances of false memories suggest that the early stages of AD impair monitoring processes that would otherwise oppose memory errors (see Schacter, Norman, & Koutstaal, 1998). But unlike decreases in true memory, increased memory errors are not always obtained in patients with AD (e.g., Balota al., 1999; Watson, Balota, & Sergent-Marshall, 2001), and exactly how monitoring processes are affected is still unclear.

One popular method of investigating such monitoring processes is to pit recall (or recollection) in opposition to familiarity on a recognition memory test (see Yonelinas, 2002, for a review). Here, *recall* refers to the ability to bring to mind previously encountered information in response to some retrieval cue, and *familiarity* denotes a feeling of "oldness" toward a questionable event. Evidence suggests that patients with AD have impaired recall, relative to familiarity. For instance, patients with AD tend to be impaired more on recall than on recognition tests (Bartok et al., 1997), and on recognition tests, subjective judgments indicate that "remembering" (recollection) is affected more than "knowing" (familiarity) in patients with AD (Dalla Barba, 1997). Task comparisons and comparisons of subjective judgments across groups must be made with caution, but taken together, these findings point to a disproportionate deficit in recall. Given this pattern of impairments, one might expect that patients with AD will perform poorly on tasks in which recall is necessary to oppose familiarity-based false recognition.

The findings from two tasks are relevant to the impaired recall-to-reject hypothesis in AD. The first was a word-stem completion task, in which subjects were required to complete word stems without using words that had been previously studied. Because the generation of studied words was facilitated (or primed) by prior presentation, these responses had to be inhibited by recollecting that these words were presented in the earlier phase. Using this task, both Knight (1998) and Koivisto, Portin, Seinela, and Rinne (1998) found that patients with AD were less likely than were control subjects to use recollection to inhibit erroneous responses. These findings indicate that recollective deficits in AD can lead to more errors, although these types of errors are different from the familiarity-based false memories that can be observed on recognition memory tests.

Research using the Deese–Roediger–McDermott (DRM; Deese, 1959; Roediger & McDermott, 1995) false-recognition task may be more relevant. In this task, false recognition of nonstudied lures is elicited by having subjects study lists of associates (e.g., Roediger & McDermott, 1995). Under typical conditions, patients with AD tend to show similar or even decreased levels of false recognition of related lures compared with age-matched control subjects

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(e.g., Balota et al., 1999; Budson et al., 2000). This finding is inconsistent with the hypothesis that patients will show greater familiarity-based false recognition because of recollection deficits. Patients did have greater false recognition of unrelated lures in these studies, but this finding might reflect liberal response criteria as opposed to impaired recall-based monitoring processes. In general, the basic DRM task is not well suited to investigate recall-to-reject processes, because such processes may be of little use under these conditions, even in younger adults (Gallo, 2004). In a modification of the DRM task, in which study and test trials were repeated five times, Budson et al. (2000) demonstrated that false recognition effects increased in patients across trials but decreased in control subjects. With repeated study/test opportunities, control subjects may have increased their recollection of the studied items and determined that the related lures were not presented, rejecting these lures as nonstudied at test. The patients were unable to use such a monitoring process to reduce false recognition, as repeated study/test trials actually increased false alarms to related lures (ostensibly by strengthening gist-based familiarity).

These last results are consistent with the idea that patients with AD are impaired in their ability to use recall or recollection to reduce familiarity-based false recognition, but other interpretations are possible. In the repeated study/test task, the subject needs to monitor several sources of activation to avoid false recognition, such as whether the related lure was in the study list, in the test list, or only imagined (Budson et al., 2002; Kensinger & Schacter, 1999; Schacter, Verfaellie, Anes, & Racine, 1998). Source memory is known to be impaired in AD (e.g., Dalla Barba, Nedjam, & DuBois, 1999; Multhaup & Balota, 1997; Smith & Knight, 2002), so that difficulties rejecting the related lure may have been due to impairments in source memory as opposed to a recall-to-reject process per se. Further, monitoring of the lure in the DRM task is sometimes achieved by "figuring out" the missing word during study (e.g., Gallo, Roberts, & Seamon, 1997). An inability to determine the related lure across trials would have led to greater levels of false recognition in patients with AD, irrespective of impairments in either source memory or recall-to-reject processes. More research is needed using tasks in which the effects of recall-to-reject can be more cleanly separated from other monitoring processes.

To more directly investigate recall-to-reject processes in AD, we used an associative recognition task in the present study. In this task, subjects study pairs of unrelated words for a subsequent test. On the test, they need to discriminate intact pairs (words that were studied in the same pair) from rearranged pairs (words that were studied but in different pairs). Because both types of test pairs are made from studied words, the test words should be equally familiar. Thus, the discrimination between intact and rearranged pairs depends on memory for the specific associations that were formed at study. The retrieval of associative information for intact pairs would lead to a hit, whereas the retrieval of associative information corresponding to rearranged pairs would lead to a correct rejection (because subjects would realize that the words had been studied in different pairs). To our knowledge, ours is the first study to investigate this type of associative recognition in AD.

It has long been thought that a recall-to-reject process could contribute to associative recognition (e.g., Humphreys, 1978), and several findings are consistent with this idea. Converging evidence comes from the interpretation of receiver operating characteristic curves (Rotello, Macmillan, & Van Tassel, 2000; Yonelinas, 1997), speeded recognition tests (Dosher, 1984; Rotello & Heit, 2000), and the effects of study repetitions (e.g., R. Kelley & Wixted, 2001), all of which indicate that the correct rejection of rearranged pairs occurs more frequently than would be expected if only a familiarity-based process were involved. For example, Rotello and Heit (2000) had healthy young adults study word pairs and then take an associative recognition test in which they were given signals to respond at various intervals (ranging from 100 ms to 2 s). As expected, the hit rate to intact pairs steadily increased with more retrieval time (from .12 to .78 in Experiment 1). In contrast, false alarms to rearranged pairs increased from 100 ms to 500 ms (.19 to .34) but then decreased from 500 ms to 2 s (.19). The initial increase was thought to reflect the accrual of familiarity, whereas the eventual decrease was thought to reflect the more time-consuming process of recollecting the appropriate pair and rejecting the rearranged pair. Other evidence also supports the conclusion that recall makes a significant contribution to the associative recognition task. Using subjective judgments, Hockley and Consoli (1999) found that associative recognition engenders more *remember* judgments than does typical single-word recognition, and by using event-related potentials, Donaldson and Rugg (1998) found that neural correlates of recollection were frequently associated with responses to both intact and rearranged pairs.

On the basis of their cognitive deficits, we expected that subjects with AD would perform more poorly on the associative recognition task than would healthy age-matched control subjects. Of special interest was the resulting pattern of errors across groups. Prior work shows that subjects with AD have cued-recall deficits in associative-learning tasks (e.g., Duchek, Cheney, Ferraro, & Storandt, 1991; Granholm & Butters, 1988). If a similar type of recall can be used to reject rearranged lures in the associative recognition task, then subjects with AD should be less likely to use such a process than control subjects, leading to enhanced false recognition. However, under conditions in which recall-to-reject is difficult even for controls, subjects with AD might show similar levels of false alarms to rearranged pairs as control subjects, or even lower levels, because of a decrease in familiarity-based processes (e.g., Budson et al., 2000; Smith & Knight, 2002).

We manipulated the number of repetitions of study pairs as a means of influencing the effectiveness of a recall-to-reject process. Intact and rearranged test pairs either contained words that had been presented once or three times at study. Using a similar manipulation with younger adults, R. Kelley and Wixted (2001) showed that repetition increased hits to intact pairs (from .54 to .89 in Experiment 1) but did not affect false alarms to rearranged pairs (.23 to .25). They interpreted these results as consistent with two opposing effects of repetition (cf. Jacoby, 1999). Repetition increased the familiarity of the rearranged pairs, which should have increased false alarms, but it also increased the ability to recall the appropriate pair and thus to reduce false alarms by a recall-to-reject strategy. These two processes canceled out on average, leaving no effects of repetition. If this analysis is correct, and if AD subjects are more impaired in recall than in familiarity (and hence, in using a recall-to-reject strategy), then AD subjects' false alarms to rearranged pairs should be influenced more by repetition-induced familiarity than those of control subjects.

Method

Subjects

Twelve subjects with clinical diagnosis of probable AD (using National Institute of Neurological and Communications Disorders and Stroke and Alzheimer's Disease and Related Disorders Association criteria; McKhann et al., 1984) and 12 healthy control subjects participated in the experiment. The subjects were recruited from the Memory Disorders Unit at Brigham and Women's Hospital (Boston, MA), and older adults were community-dwelling residents of the surrounding area. Subjects with AD were matched with control subjects on the basis of age (AD subject $M = 74.1$ years, range = 55–89; control $M = 74.8$, range = 63–85), years of education (AD subject $M = 16.9$, range = 12–24; control $M = 15.9$, range = 12–20), and gender (5 female AD subjects and 7 female control subjects), and all had normal or corrected-to-normal vision and hearing. On average, control subjects scored higher than did subjects with AD on the Mini-Mental Status Examination (Folstein, Folstein, & McHugh, 1975), control $M = 29.1$ (range = 28–30), AD subject $M = 25.4$ (range = 21–29), $t(22) = 5.12$, $p < .01$. Subjects were excluded on the basis of clinical depression, alcohol or drug use, cerebrovascular disease, traumatic brain damage, or a primary language other than English. Also, data from one subject were replaced because the subject used the "old" response only twice on the recognition test (less than 2% of the trials). All participants were paid $10/hr for their participation.

Materials and Design

Stimuli were 228 words drawn from the MRC Psycholinguistic Database (Coltheart, 1981). The words had high imagery ratings (ranging from 5.5 to 7 on a scale of 1–7, $M = 6$, $SD = 0.22$), and those that appeared to elicit very similar mental images were excluded. Words ranged from three to seven letters ($M = 4.7$, $SD = 1$) and had an average printed frequency of 37.5 per million, $SD = 55.6$ (14 words were excluded from this mean because they were not listed in Kucera & Francis, 1967). Six word pairs were formed to be used as study buffers (3 at the beginning and 3 at the end of the study list). The remaining 216 words were divided into 108 study pairs (e.g., *kite-river; fire-flute*), and rearranged test pairs were created by switching the second words of two yoked study pairs (e.g., *kite-flute; fire-river*). The words within each pair (intact or rearranged) had no obvious semantic relationship to each other. The study pairs were then arranged into six sets of 18 pairs, for counterbalancing.

Subjects saw 72 study pairs (in addition to the 6 buffer pairs). Half of the study pairs were presented once, and half were presented three times. The presentation order of study pairs was randomized for each subject. There were 108 test pairs (one third intact, one third rearranged, one third nonstudied), and these also were randomized for each subject. Half of the studied pairs were re-presented at test (intact pairs), and half were rearranged at test (rearranged pairs), so that each study word was presented only once at test. For the intact and rearranged pairs, half of the test pairs contained words that had been presented once at study (1×), and half contained words that had been presented three times (3×). For the pairs of nonstudied words, half were arranged at test as they would be if they had been studied (intact), and half were rearranged. Across the six counterbalancing conditions, each set of 18 pairs contributed once to each type of test pair (i.e., intact-3×, intact-1×, rearranged-3×, rearranged-1×, nonstudied-intact, and nonstudied-rearranged).

Procedure

Study and test pairs were presented in black letters on a white computer screen using PsyScope software. Each pair was presented in large uppercase letters, with the words of a pair separated by three dashes (*FIRE---RIVER*). Subjects were told that they would study word pairs and that some would repeat. To minimize inevitable group differences at encoding, all subjects were given a deep orienting task. For each word pair, they were told to link the two words together because their memory would later be tested. As potential ways to link the words together, subjects were told to use a mental image or a sentence. Hockley and Cristi (1996) found that these two tasks yielded similar levels of single-word and associative recognition, and both options were given in the present experiment because a few pilot subjects preferred to form sentences even when given imagery instructions. The study phase was self-paced, and for each pair, subjects said whether it was "easy" or "hard" to link the words together. The experimenter recorded this response with a keypress that initiated the presentation of the next pair.

The test also was self-paced. Subjects said whether each pair was "old" or "new," and the experimenter again recorded this response with a keypress that initiated the next trial. Subjects were told that old pairs were two words that were originally studied together in the exact same pair. New pairs were words that were not studied together in the exact same pair—they were either studied in different pairs, or they were never studied at all. They were told to respond "old" only if they remembered linking those exact two words together at study and to respond "new" if they remembered that the words were paired with different words, or if they did not remember the words at all. Care was taken to ensure that each subject understood these instructions.

Results and Discussion

Study Phase

As might be expected, the subjects with AD took longer to decide how difficult it was to link the words together ($M = 7{,}912$ ms) than did the control subjects ($M = 3{,}923$ ms). For both groups, these decisions were made more quickly when repeated pairs were re-presented at study (for control subjects, latencies decreased from 4,542 to 3,424 to 3,002, and for subjects with AD, latencies decreased from 10,558 to 7,055 to 5,777). A 3 (repetition order) × 2 (group) ANOVA confirmed a main effect of group, $F(1, 22) = 7.49$, $MSE = 41{,}183{,}217$; a main effect of repetition, $F(2, 44) = 26.24$, $MSE = 2{,}446{,}292$; and a Group × Repetition interaction, $F(2, 44) = 6.92$, $MSE = 2{,}446{,}292$. (Unless noted otherwise, all statistical results reported in this article were significant at $p < .05$.) Repeating pairs facilitated their acquisition, and this priming or practice effect was larger for the AD subjects.[1] Latencies to once-presented pairs did not differ as a function of whether they were presented in the first or second half of the study phase ($M = 4{,}622$ and 4,828 for control subjects and 8,522 and 7,994 for AD subjects, ps $> .10$), supporting the idea that the decrease in latencies for repeated pairs was due to priming, as opposed to their different positions in the study phase. These priming effects suggest that both groups were following instructions and were trying to link the words together at study.

Test Phase

Data from the old–new judgments are found in Table 1 and can be easily summarized. Subjects with AD correctly recognized

[1] A similar ANOVA on the proportion of *easy* judgments revealed a marginal effect of group, $F(1, 22) = 3.29$, $MSE = 0.229$, $p = .08$, as the subjects with AD tended to make more easy judgments (.74) than did the control subjects (.55). However, because of the cognitive deficits in AD and because the experimenter recorded responses in both groups (introducing a social component), these subjective judgments probably are not a valid measure of objective difficulty across groups. There was no effect of repetition and no interaction (Fs < 1).

Table 1
Mean Proportion of Test Pairs Recognized as Old as a Function of Study Repetition

Test pair	Control subjects	AD subjects
Same-1×	.77 (.06)	.57 (.05)
Same-3×	.94 (.02)	.83 (.04)
Rearranged-1×	.19 (.05)	.47 (.07)
Rearranged-3×	.16 (.07)	.61 (.06)
Nonstudied	.01 (.01)	.25 (.06)

Note. Standard errors of each mean are in parentheses.

fewer intact pairs than did control subjects, and they made more false alarms to all lures. Repetition increased recognition of intact pairs in both groups, but repetition had different effects on false alarms to rearranged pairs across groups. For control subjects, false alarms to rearranged pairs were not affected by having repeatedly studied each member of the pair, whereas repetition increased false alarms in the subjects with AD. A 2 (pair type: intact or rearranged) × 2 (repetition) × 2 (group) ANOVA indicated a main effect of pair type, $F(1, 22) = 89.43$, $MSE = 0.047$; a main effect of repetition, $F(1, 22) = 26.11$, $MSE = 0.017$; and three significant interactions: pair type × repetition, $F(1, 22) = 12$, $MSE = 0.013$; pair type × group, $F = 33.75$, $MSE = 0.047$; and repetition × group, $F = 5.77$, $MSE = 0.017$. In what follows, we first report analyses of each group separately and then compare the two groups.

In the controls, a 2 (pair type: intact or rearranged) × 2 (repetition) ANOVA revealed a main effect of pair type, $F(1, 11) = 116.60$, $MSE = 0.047$. Hits to intact pairs ($M = .86$, collapsed across repetitions) were greater than false alarms to rearranged pairs ($M = .18$), demonstrating significant levels of associative recognition. There was a marginal effect of repetition, $F(1, 11) = 4.76$, $MSE = 0.062$, $p = .05$, and a significant interaction, $F(1, 11) = 11.59$, $MSE = 0.009$. The interaction reveals that repetition increased hits to intact pairs, from .77 (once) to .94 (three times), $t(11) = 3.15$, $SEM = 0.053$, but repetition had no effects on false alarms to rearranged pairs (.19 [once] and .16 [three times]), $t(11) < 1$. If anything, false alarms to rearranged pairs were slightly lower when the members of the pair had been repeated at study.

This pattern suggests that control subjects used recall to reject a rearranged pair (e.g., R. Kelley & Wixted, 2001). Having studied the words in a rearranged pair clearly made them more familiar, as false alarms to rearranged pairs (.19 for once-presented pairs) were greater than were false alarms to pairs of nonstudied words (.01), $t(11) = 3.65$, $SEM = 0.048$. Repetition of these rearranged pairs should have increased their familiarity even more, causing an increase in false alarms. The fact that rearranged false alarms did not increase with repetition suggests that this effect was offset by increases in the ability to recall the correct pair with repetitions (and hence use a recall-to-reject strategy).

In the AD subjects, a similar ANOVA revealed a main effect of pair type, $F(1, 11) = 6.65$, $MSE = 0.047$. This analysis again indicates significant levels of associative recognition, as hits to intact pairs (.70, collapsed across repetitions) were greater than false alarms to rearranged pairs (.54). There also was a main effect of repetition, $F(1, 11) = 22.93$, $MSE = 0.021$, and no interaction, $F(1, 11) = 3.12$, $p > .10$. This finding indicates that repetition increased hits to intact pairs (.57 vs. .83) and, more telling, that repetition also increased false alarms to rearranged pairs (.47 vs. .61). Unlike the control subjects, subjects with AD were not able to eliminate the effects of repetition on rearranged pairs with a recall-to-reject strategy. Finally, as with control subjects, false alarms to rearranged pairs (.47 for once-presented pairs) were greater than false alarms to pairs of nonstudied words (.25), $t(11) = 4.44$, $SEM = 0.051$, demonstrating familiarity-based false recognition.

Group Comparisons

Two types of memory discrimination (pair memory and associative memory) were calculated to compare performance across groups. Pair memory was calculated as the difference between hits to intact pairs and false alarms to pairs of nonstudied words. This difference reflects the effects of studying a word pair on accurate memory, such as the recollection (or familiarity) of the association between the words or simply that studied words are more familiar than nonstudied words.[2] Associative memory was calculated as the difference between hits to intact pairs and false alarms to rearranged pairs. The individual words in intact and rearranged pairs should have been equally familiar, because in both cases the words were presented at study. Thus, the ability to discriminate between intact and rearranged pairs reflects memory for the associations formed at study, either by increasing hits to intact pairs or by decreasing false alarms to rearranged pairs by a recall-to-reject process.

Table 2 presents pair-memory and associative-memory scores for each group. As can be seen from the table, patients were impaired relative to control subjects in each of the comparisons. Of particular interest is whether these impairments interacted with the type of memory discrimination. A 2 (discrimination: pair memory or associative memory) × 2 (repetition) × 2 (group) ANOVA revealed a main effect of discrimination, $F(1, 22) = 41.89$, $MSE = 0.03$, a main effect of repetition, $F(1, 22) = 28.65$, $MSE = 0.03$, and a main effect of group, $F(1, 22) = 35.76$, $MSE = 0.137$. The three-way interaction was also significant, $F(1, 22) = 4.35$, $MSE = 0.009$, and there were no other significant interactions.

To follow up the interaction, a 2 (discrimination) × 2 (group) ANOVA was conducted separately for each level of repetition. For pairs that were presented once, there was a main effect of discrimination, $F(1, 22) = 32.87$, $MSE = 0.015$, a main effect of group, $F(1, 22) = 27.69$, $MSE = 0.092$, and no interaction ($F < 1$). The lack of an interaction indicates that, compared with control subjects, subjects with AD were equally impaired in their ability to discriminate intact pairs from nonstudied pairs (a decrement of .44) as they were in their ability to discriminate intact pairs from rearranged pairs (a decrement of .48). Of course, because the same hit rates contributed to each of these means, this pattern is attributable to the fact that false alarms to nonstudied pairs and rearranged pairs increased by roughly the same amount in the subjects

[2] This measure was used over other measures of discrimination (d' or A') because it tends to be more sensitive (Snodgrass & Corwin, 1988) and because it may be more appropriate for the associative discrimination (see Yonelinas, 1997, for relevant findings).

Table 2
Memory Discriminations as a Function of Study Repetition

Measure	Control subjects	AD subjects	Difference
Pair memory			
1×	.76 (.06)	.32 (.07)	.44
3×	.93 (.03)	.59 (.07)	.34
Associative memory			
1×	.58 (.07)	.10 (.07)	.48
3×	.77 (.07)	.23 (.07)	.54

Note. Pair memory is intact hits minus false alarms to pairs of nonstudied words. Associative memory is intact hits minus rearranged false alarms. Standard errors of each mean are in parentheses.

with AD relative to control subjects (.24 and .28, respectively; see Table 1). Thus, if false alarms to rearranged pairs are adjusted to account for the different levels of false alarms to nonstudied pairs (via subtraction), then the two groups showed similar effects of a single study presentation on familiarity-based false alarms: .18 for control subjects vs. .22 for AD subjects, $t(22) < 1$.

A different pattern emerged in the analysis of the repeated pairs, which afforded more opportunity for a recall-to-reject strategy. There was a main effect of discrimination, $F(1, 22) = 33.24$, $MSE = 0.024$; a main effect of group, $F(1, 22) = 31.61$, $MSE = 0.074$; and a significant Discrimination × Group interaction, $F(1, 22) = 5.46$, $MSE = 0.024$. The interaction indicates that the AD deficit was larger for associative memory (.54) than for pair memory (.34). This pattern is attributable to the fact that false alarms to rearranged pairs had increased more with AD subjects, relative to control subjects, than did false alarms to nonstudied pairs (an increase of .45 and .24, respectively). If false alarms to rearranged pairs are again adjusted for false alarms to nonstudied pairs, the subjects with AD now showed greater levels of false recognition (.36) than did the control subjects (.15), $t(22) = 2.34$, $SEM = 0.089$. This disproportionate increase in rearranged false alarms is consistent with the idea that the patients were impaired in the ability to use a recall-to-reject strategy for these pairs.

As a final analysis, we compared performance with three times-presented pairs for the subjects with AD with once-presented pairs for the controls. This procedure allowed for a closer matching of subjects with AD and control subjects on the pair discrimination, which could be accomplished solely by assessing the familiarity of the words in the pair. If the control subjects were more likely to use the recollection of associations, then the subjects with AD should be impaired on the associative discrimination even when they are matched with control subjects on the pair discrimination. These data are presented in the left panel of Figure 1, in which it can be seen that there was a main effect of group, $F(1, 22) = 9.21$, $MSE = 0.091$; a main effect of memory type, $F(1, 22) = 47.05$, $MSE = 0.018$; and a Group × Memory Type interaction, $F(1, 22) = 5.59$, $MSE = 0.018$. The interaction indicates that the subjects with AD were more impaired on the associative discrimination. To achieve an exact matching, we also compared the 9 subjects with AD who had the highest pair-discrimination scores ($M = .68$) with the 9 control subjects with the lowest pair-discrimination scores ($M = .69$).[3] These data are presented on the right side of Figure 1. Here it can be seen that the subjects with AD were still impaired on associative discrimination (.25) relative to control subjects (.54), $t(16) = 2.62$, $MSE = 0.111$. Thus, even when the two groups were matched on their ability to discriminate intact pairs from nonstudied pairs, the subjects with AD were impaired on the associative discrimination.

General Discussion

The present results indicate that subjects with AD are impaired in the ability to use recall to reduce familiarity-based false recognition, leaving them more prone to false recognition. Whereas control subjects were able to use a recall-to-reject process to overcome the influences of repetition on rearranged pairs, repetition increased false alarms to rearranged pairs in the subjects with AD. Even when the groups were more closely equated on the discrimination between intact pairs and pairs of nonstudied words, the subjects with AD made more false alarms to rearranged pairs than did the control subjects. These results are consistent with prior work demonstrating that subjects with AD have difficulties using repeated study–test phases to edit out false recognition of related lures (Budson et al., 2000), but unlike previous results, the present findings cannot be attributed to deficits in source memory. In the present task, monitoring processes are based on the recall of specific associations formed at study.

These observations do not imply that there was no memory for associative information in subjects with AD, or that control subjects were not susceptible to familiarity-based false recognition. The subjects with AD did show significant associative recognition in the 3× condition, indicating that they were actively recruiting associative information to perform the task. Also, control subjects showed more false alarms to rearranged pairs than to pairs of nonstudied words, indicating that they too were susceptible to familiarity-based false recognition. The present results instead indicate that control subjects were relatively more likely than were subjects with AD to use a recall-to-reject process to overcome familiarity effects.

Analysis of the two types of memory discriminations bolstered this conclusion. In the 1× condition, pair memory and associative memory were equally impaired in AD, whereas in the 3× condition, associative memory was differentially impaired. These seemingly conflicting findings make sense if a recall-to-reject process was involved. In the 1× condition, after adjusting for false alarms to nonstudied pairs, control subjects and subjects with AD showed equivalent levels of rearranged false alarms. This finding suggests that a recall-to-reject process was difficult when the to-be-recalled members of a rearranged pair were presented only once at study. As a result, the two groups showed the same influence of prior presentation on familiarity-based false alarms. With three presentations of the to-be-recalled items, control subjects were now able

[3] Analysis of this attenuated data set yielded the same results as the entire data set. For control subjects, there was a main effect of pair type, $F(1, 8) = 147.33$, $MSE = 0.027$; a marginal effect of repetition, $F(1, 8) = 5.14$, $MSE = 0.014$, $p = .05$; and a significant Pair Type × Repetition interaction, $F(1, 8) = 15.02$, $MSE = 0.009$. Repetition increased hits to intact pairs, .70 to .91, $t(8) = 3.25$, $SEM = 0.065$, but did not affect false alarms to rearranged pairs, .16 to .13, $t(8) = -1.05$. For AD subjects, there was a main effect of pair type, $F(1, 8) = 6.20$, $MSE = 0.058$; a main effect of repetition, $F(1, 8) = 75.08$, $MSE = 0.008$; and no interaction, $F(1, 8) = 1.70$, $p > .20$. Repetition increased both hits (.52 to .83) and false alarms (.38 to .58).

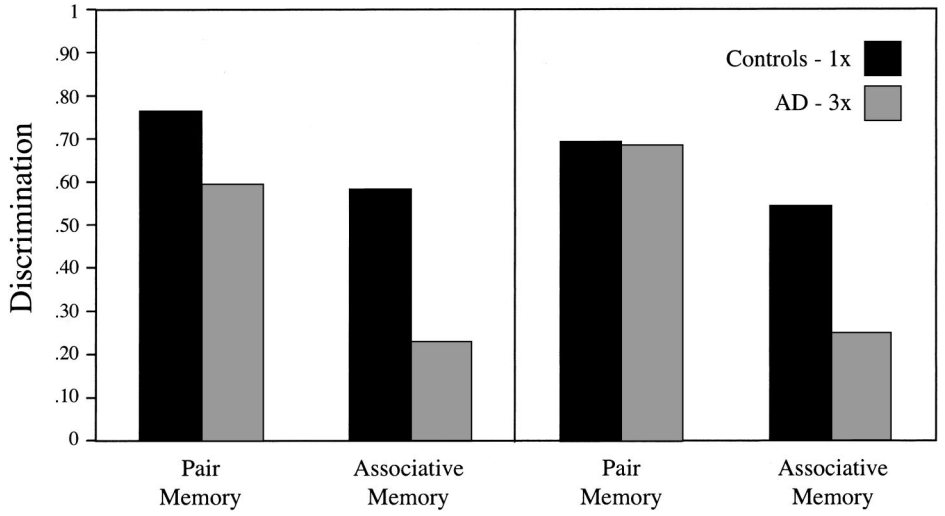

Figure 1. Pair memory and associative memory for AD subjects (3×) and control subjects (1×). Left: Discrimination data (hits minus false alarms) from all 24 subjects. Right: Discrimination data (hits minus false alarms) from the 18 subjects equated on pair memory.

to take advantage of a recall-to-reject process to counter the influences of repetition on familiarity, whereas the subjects with AD were not. Rearranged false alarms increased and associative discrimination decreased in subjects with AD, relative to control subjects.

These findings highlight the point that associative recognition is not a process-pure task. Naveh-Benjamin (2000) argued that larger age-related deficits in associative recognition, relative to single-word recognition, implicate an age-related associative deficit. The present comparisons between associative memory and pair memory are analogous to those comparisons, because pair discriminations could be based in part on familiarity of the individual words (much like the case with single-word recognition). However, we caution against interpreting the present findings as evidence for or against a selective impairment of associative memory in AD (relative to healthy aging). Associative-recognition performance is influenced by both the ability to recognize intact pairs and by the ability to engage recall-to-reject monitoring processes on rearranged pairs, and either could lead to a relatively larger deficit in the associative discrimination. As such, disproportionate impairments of associative recognition compared with pair recognition (or single-word recognition) could be based on several factors, including impaired memory for associations, difficulties engaging recollection-based monitoring processes (in the absence of associative memory deficits), or both.

Given this interpretative limitation, a fruitful avenue for further research will be to more directly investigate associative memory deficits in AD. One approach would be to use a variety of associative-memory tasks that have been used in older adults and populations of subjects with AD, such as those developed by Naveh-Benjamin (2000) and others (e.g., Chalfonte & Johnson, 1996; Swainson et al., 2001). Another approach would be to modify the current associative-recognition task to isolate the associative-memory component, which could be achieved by rendering the recall-to-reject process ineffective. For instance, by repeating some of the studied words in different pairs (e.g., *kite-river, fire-flute, kite-house*), the recall of one pair (*kite-river*) would not necessitate the rejection of a rearranged pair (*kite-flute*), because both pairs could be studied under this design. This manipulation would not affect the basis of responding to an intact pair, but it might minimize the rule-based recall-to-reject component for rearranged pairs. As a result, false alarms to rearranged pairs would be a cleaner estimate of the familiarity of individual studied words, and the associative discrimination (intact minus rearranged) would better reflect the recognition of the association between members of the intact pair.

Regardless of whether associative memory is differentially impaired in AD, it is clear from the present findings that mild AD impairs monitoring processes that could reduce false recognition. The widespread cortical damage and neurochemical changes that characterize AD probably impair such processes in at least two ways. First, damage to medial-temporal lobe regions (and others) might reduce the likelihood of forming or retrieving associations (e.g., Eichenbaum & Cohen, 2001), which would preclude the use of such information in a recall-to-reject process. Neuroimaging evidence in younger adults suggests that medial-temporal regions are critically involved in associative-recognition tasks for words, both at encoding (Jackson & Schacter, 2004) and at retrieval (Giovanello, Schnyer, & Verfaellie, 2004; Yonelinas, Hopfinger, Buonocore, Kroll, & Baynes, 2001). Consistent with the hypothesis that impaired MTL function might affect associative binding in AD, Sperling et al. (2003) found that subjects with AD had decreased encoding activation in the hippocampal formation in a face–name association task, compared with healthy age-matched control subjects.

Second, even if associative information is available to subjects with AD, frontal dysfunction might impair their ability to strategically use this information to oppose familiarity-based false recognition (e.g., Budson et al., 2002; Moscovitch, 1994). Neuroimaging evidence in younger adults suggests that frontal regions, including left inferior prefrontal cortex, are highly involved in the retrieval of associative information (e.g., Badgaiyan, Schacter, &

Alpert, 2002), and these effects may reflect the strategic components of associative recognition (see Van Petten, Luka, Rubin & Ryan, 2002, for relevant findings and discussion). Impairments in either of these domains—memory for associations or the engagement of monitoring processes—could impair recall-to-reject processes and render subjects with AD more prone to false recognition.

In conclusion, it is important to point out that we found greater familiarity-based false recognition in AD subjects only when control subjects were most likely to use recall processes to oppose these effects (i.e., when pairs were presented three times). When pairs were only presented once, the two groups showed equivalent effects of familiarity on false recognition. This pattern suggests that greater levels of familiarity-based false recognition are not an inevitable consequence of AD but depend on whether control subjects are able to engage recall-based monitoring processes to keep the influences of familiarity in check. This is not to say, though, that overall levels of false recognition were not greater in AD. False alarms to unrelated pairs were greater in subjects with AD than in control subjects, and false alarms to 1×-rearranged pairs were also elevated by this same amount. Because a recall-to-reject strategy would not apply to unrelated pairs, these increases suggest that another monitoring component, such as response criteria setting, is also impaired in AD. In general, the monitoring of memory accuracy may be composed of several interrelated processes (e.g., Gallo, 2004; C. M. Kelley & Sahakyan, 2003; Koriat & Goldsmith, 1996). To fully understand the memory impairments in AD, or in any special population, researchers need to conduct more work using tasks that separate these various aspects of monitoring.

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