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When False Recognition Is Unopposed by True Recognition: Gist-Based Memory Distortion in Alzheimer's Disease

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The authors examined false recognition of semantic associates in patients with probable Alzheimer's disease (AD), older adults, and young adults using a paradigm that provided rates of false recognition after single and multiple exposures to word lists. Using corrected false recognition scores to control for unrelated false alarms, the authors found that (a) the level of false recognition after a single list exposure was lower in AD patients than in controls; (b) across 5 trials, false recognition increased in AD patients, decreased in young adults, and showed a fluctuating pattern in older adults; and (c) all groups showed an increase in true recognition over the 5 trials. Analyses suggested that AD patients built up semantic gist across trials, whereas both control groups were able to use increased item-specific recollection and more conservative response criteria to suppress gist-based false alarms.

Patients with probable Alzheimer's disease (AD) not only fail to retrieve desired information but also suffer from distortions of memory (Förstl et al., 1994). These memory distortions may impair the ability of the patient with probable AD to live independently (Borson & Raskind, 1997). Although sometimes these distortions can be extreme, as in syndromes of delusional misidentification (Capgras syndrome and reduplicative paramnesia, see Förstl et al., 1994 for review), frequently they are more mundane but still of clinical significance. For example, patients may believe that they turned off the stove when they have only thought about turning it off. Although memory distortions in AD are thus a clinically important issue, the cause of these distortions has been largely unexplored.

Much of the previous work on memory distortion in AD has examined the tendency to produce unstudied items or intrusions on memory tests. Drachman and Leavitt (1974) showed that they could induce intrusion errors on retrieval of words from semantic memory in young adults by administration of anticholinergic medication. Disruption of cholinergic systems has been shown to be important in the memory dysfunction of AD (Mesulam, 1996). Fuld, Katzman, Davies, and Terry (1982) found that intrusions are common in patients with AD and that they correlate with low levels of choline acetyletransferase and high numbers of senile plaques in the cerebral cortex. They concluded that intrusions were sufficiently characteristic of AD to be helpful diagnostically.

A few studies of AD patients examined the frequency of semantically and conceptually related intrusions (e.g., *glass* for *cup, screw* for *nail*) versus unrelated intrusions (e.g., *dog* for *nail*). Loewenstein et al. (1989) examined conceptually related versus unrelated intrusions that patients with AD produced on the Fuld Object Memory Evaluation (Fuld, Katzman, Davies, & Terry, 1982). They found that a majority of AD patients produced unrelated intrusions, whereas controls produced no unrelated intrusions. However, they also found a nonsignificant trend for AD patients to produce fewer conceptually related intrusions than controls. Dalla Barba and Wong (1995) found that AD patients made a high proportion of unrelated intrusions when attempting to retrieve a list of words that were not related to one another. When AD patients were asked to retrieve a list of semantically associated words, the production of related intrusions was found to be associated with the absence of a semantic memory deficit, as defined by normal performance on tests that utilize semantic memory stores (e.g., the ability to generate words in a specified category over 1 min).

Memory distortion in AD has recently been examined with a paradigm that allows measurement not only of semantically related and unrelated intrusions, but also of a similar type of memory distortion known as *false recogni-*

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tion, which occurs when people incorrectly claim to have previously encountered a novel item that is in some way related to a previously studied item. False recognition has been studied more extensively and analytically than have recall intrusions (see Schacter, Norman, & Koutstaal, 1998), and therefore may allow insights into memory distortion in AD patients that would be difficult to obtain from studies of intrusion errors. Recent experiments using a paradigm originally developed by Deese (1959) and revived and modified by Roediger and McDermott (1995) have demonstrated robust levels of false recognition in healthy adults. After studying lists of semantic associates (e.g., *candy, sour, sugar, bitter, good, taste,* and so forth) that all converge on a nonpresented "theme word" or "related lure" (e.g., *sweet*), participants frequently intruded the related lure on free recall tests (Deese, 1959), and made very high levels of false alarms to these words on recognition tests (Roediger & McDermott, 1995). (It is important to note that although false recognition of unrelated items is occasionally discussed below, use of the unqualified term *false recognition* always refers to false recognition of related lures.)

Balota et al. (1999) used the Deese/Roediger–McDermott paradigm and found that, compared with healthy older adults, AD patients showed dramatic impairment in their recall of studied words and were more likely to produce unrelated intrusions. However, there was little difference between these groups in their likelihood of intruding the related lures. Balota et al. found that AD patients falsely recognized more unrelated lures and fewer related lures than did healthy older adults. These researchers also analyzed the data from a subset of their participants who were chosen on the basis of their level of true recognition performance (i.e., how well they were able to correctly recognize previously studied words). They hypothesized that if one could control for the effects of the AD patients' poor memory for studied words, AD patients would then show increased (rather than decreased) rates of false recognition. By choosing the subset of AD patients who showed relatively higher levels of true recognition and the subset of older adult controls who showed relatively lower levels of true recognition, they were able to match rates of true recognition. Analysis of the data from these selected and matched groups showed that AD patients were indeed more likely than controls to falsely recognize related lures. Thus, when Balota et al. used data from all participants, they found that AD patients were less likely than older adults to falsely recognize related lures, but, when they controlled for true recognition, Balota et al. found that AD patients were more likely than older adults to falsely recognize related lures.

One interpretation of these results is suggested by the idea that true and false recognition depend on memory for two different kinds of information: specific details of a prior encounter with a particular item (item-specific recollection) and the general meaning, idea, or gist conveyed by a collection of items (gist information; e.g., Reyna & Brainerd, 1995). As the study list is presented in the Deese/Roediger–McDermott paradigm, a gist representation is developed, which may result in an experience of recollection or familiarity when either a studied item or a related lure is presented on a later recognition test. Thus, in the Deese/Roediger–McDermott paradigm, accurate recognition of previously studied items probably depends on both item-specific and gist information, whereas false recognition of related lure words depends on remembering gist but not item-specific information (cf., Brainerd & Reyna, 1998; Payne, Elie, Blackwell, & Neuschatz, 1996; Schacter, Verfaellie, & Pradere, 1996). The fact that AD patients showed lower levels of overall true and false recognition than did controls suggests that AD patients have impaired access to both item-specific and gist information. However, the fact that AD patients showed higher levels of false recognition than controls when levels of true recognition were equated suggests that AD patients depend somewhat more on memory for gist information than do controls.

To explore further the implications of these observations in AD patients, we made use of a paradigm for investigating false recognition that has been reported recently in a study of amnesic patients by Schacter, Verfaellie, Anes, and Racine (1998; cf. McDermott, 1996). Amnesic patients exhibit severe difficulties remembering recent experiences as a consequence of damage to the medial temporal lobes and related structures in the diencephalon, despite normal perceptual and linguistic functions and IQ scores in the normal range (e.g., Parkin & Leng, 1993; Squire, 1994). Schacter, Verfaellie, et al. (1998) studied amnesic patients using a modified version of the Deese/Roediger–McDermott paradigm in which there were five study–test trials. They found that on the first trial, amnesic patients made fewer correct responses to old items and fewer false alarms to related lures than did controls (see also, Schacter, Verfaellie, & Anes, 1997; Schacter, Verfaellie, & Pradere, 1996). With repeated study–test trials, control participants exhibited increasing levels of true recognition together with decreasing levels of false recognition. Amnesic patients also demonstrated increased true recognition across trials but, in sharp contrast to controls, showed no evidence of decreasing false recognition across trials. Korsakoff amnesic patients exhibited increased false recognition across trials, whereas non-Korsakoff amnesic patients (e.g., those who suffered anoxia, encephalitis, or other types of damage to their medial temporal structures) showed fluctuating levels of false recognition across trials.

The reduced levels of true and false recognition observed in amnesic patients on the first trial suggest that, much as we hypothesized for AD patients in Balota et al.'s (1999) study, amnesic patients are characterized by impaired memory for both item-specific recollection (i.e., particular recollections of studied words) and semantic gist information (i.e., the general idea or meaning conveyed by each set of semantic associates). Schacter, Verfaellie, et al. (1998) further suggested that repetition of target items served to strengthen both semantic gist information and item-specific recollection in control participants. Controls were thus able to use their increasingly detailed recollections of the specific items that had been presented to counter or suppress the strengthening gist representation: By remembering more clearly which words had been presented previously, controls were either able to reject lure words because they did not have the

detailed, item-specific information of the studied words (cf. Strack and Bless, 1994) or because the increasing recollection of the studied words across trials allowed them to reduce their likelihood of gist-based false alarms. In contrast, Schacter, Verfaellie, et al. (1998) suggested that for amnesic patients, repetition served to strengthen only semantic gist information. Thus, amnesic patients developed an increasingly robust representation of the semantic gist of the list but were unable to counter or suppress the strengthening gist influence with specific recollections of items that they had studied.

Consider these ideas in relation to our suggestion that recognition judgments in AD patients, compared with healthy controls, depend more on a degraded gist representation. By this view, we would expect that in the repeated-trials paradigm used by Schacter, Verfaellie, et al. (1998), AD patients would show less false recognition on the first trial than would controls (replicating the results of Balota et al., 1999). With repetition, however, AD patients should show increasing false recognition compared with controls because they would presumably rely more heavily on the strengthening gist representation, and would be less able to use item-specific information to check or suppress the influence of semantic gist. To test these ideas, we studied patients with mild-to-moderate AD, older controls, and young adults by using a modified Deese/Roediger–McDermott paradigm similar to that used previously by Schacter, Verfaellie, et al. (1998).

Method

Twelve patients (aged 60–85 years) with a clinical diagnosis of probable AD (based on National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association criteria, McKhann, Drachman, Folstein, Katzman, & Price, 1984), 15 healthy older adults (aged 63–90 years), and 13 healthy young adults (Boston University undergraduate students, aged 18–21 years) participated in the experiment. Patients with AD were recruited from the clinical population at the Memory Disorders Unit, Brigham and Women's Hospital, Boston, Massachusetts. Healthy older adults were recruited from individuals who were participating in a longitudinal study of normal aging at Brigham and Women's Hospital, as well as from spouses and friends (but not blood relatives) of the AD patients. Young adults were recruited through fliers posted at Boston University. Written informed consent was obtained from all participants and their care-givers (where appropriate). The study was approved by the human subjects committee of Brigham and Women's Hospital. Older adults and AD patients were paid $10/hour for their participation; young adults received course credit. Young and older adults were excluded if they scored below 2 *SD*s on any element of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) Word List Memory test (memory, recall, and recognition; Morris et al., 1989; Welsh, Butters, Hughes, Mohs, & Heyman, 1992), below 30 on category word fluency (animals, fruits, vegetables; Monsch et al., 1992), or in the impaired range on either subtest of the Blessed Dementia Scale (Activities, Habits, Personality [BDS-AHP] or Information, Memory, Concentration [BDS-IMC], Blessed, Tomlinson, & Roth, 1968). Patients with AD were excluded if they scored outside of the mild-to-moderate range on the BDS-IMC (4–16; Locascio, Growdon, & Corkin, 1995). Persons were also excluded if they were characterized by clinically significant depression, alcohol, or drug use, brain damage, or if English was not their primary language. Three older and one young adult were excluded on the basis of these criteria, resulting in 6 male and 6 female participants in all groups. All participants had normal or corrected-to-normal vision. The AD patients were matched to the 12 older adults on the basis of age, education, and estimated verbal IQ as measured by The National Adult Reading Test—American Version (Am–NART; Blair & Spreen, 1989). Young adults were matched to older adults and AD patients in terms of estimated verbal IQ. In addition to the screening and matching tests, performance on controlled word fluency to letters (*F, A, S;* Monsch et al., 1992) was also recorded. Performance on these tests and group demographics are presented in Table 1.

Materials were selected from the lists of semantic associates published by Roediger and McDermott (1995) and supplemented by Stadler, Roediger, and McDermott (1999). For the study lists, two sets of six 15-word lists were chosen, Set A and Set B. For each of the six 15-word lists, there was a critical, nonpresented theme word or related lure on which all the associates converged, which was not presented during the study phase of the experiment (e.g., for the 15 word list containing the presented words *cigarette, puff, blaze, billows, pollution, ashes, cigar,* and so forth, the related lure

Table 1
Demographic and Psychometric Means, Ranges, and Significance in Alzheimer's Disease (AD) Patients, Younger Adults, and Older Adults

Measure and group	*M*	Range	*F*	*p*
Age (years)				
AD	71.58	60–85	<1.00	*ns*[a]
Older	74.25	63–90		
Younger	19.42	18–21	591.33	<.001
Education (years)				
AD	15.25	12–21	1.08	*ns*
Older	16.50	12–20		
Younger	13.42	12–15	12.31	.002
VIQ (Am–NART)				
AD	119.00	107–132	2.34	*ns*
Older	124.08	110–132		
Younger	122.33	115–130	<1.00	*ns*
BDS-AHP				
AD	4.38	2–9	34.27	<.001
Older	0.38	0–2		
Younger	0.00	0–0	4.07	.056
BDS-IMC				
AD	9.50	4–16	55.23	<.001
Older	0.08	0–1		
Younger	0.00	0–0	1.00	*ns*
Letter fluency				
AD	33.33	10–53	7.60	.011
Older	45.50	29–68		
Younger	48.67	30–65	<1.00	*ns*
Category fluency				
AD	24.67	13–32	56.64	<.001
Older	52.17	39–81		
Younger	55.00	39–69	<1.00	*ns*

Note. *ns* = $p > .100$; VIQ (Am–NART) = verbal IQ, National Adult Reading Test—American Version (Blair & Spreen, 1989); BDS-AHP = Blessed Dementia Scale (Activities, Habits, Personality; Blessed, Tomlinson, & Roth, 1968); BDS-IMC = Blessed Dementia Scale (Information, Memory, and Concentration; Blessed et al., 1968).
[a]For each, the top *F* and *p* values are for comparisons of AD patients versus older adults, and the bottom values are for comparisons between younger and older adults.

was *smoke*). The two word sets have been matched with respect to the mean false-alarm rate to the related lure word for each list, as indicated by the norms assembled by Stadler et al. (1999). Half of the participants studied only lists from Set A, and the other half studied only lists from Set B. List order was kept constant over the five study repetitions, and study words within each list were presented in the same order each time, from the highest associate to the lowest.

Participants were instructed to read the study words aloud and to remember them for a test session that would follow immediately. The words were presented on an Apple Macintosh Powerbook 5300c computer, one word at a time for 3 s each, in the center of the screen, which was placed a comfortable viewing distance from the participant. There was a 1-s interval between words. The six study lists were presented successively without interruptions. Participants were told that there would be five study–test sessions, all using the same procedure, and that the study materials would be the same and the recognition test would be different in each session.

Each test list was composed of 36 words, in a different random order for each participant. Six of these words were related lures (the nonpresented theme words). Eighteen of the tested items were studied words, with three studied words selected from Input Positions 1, 8, and 10 of each list. Twelve of the tested words were unrelated lures that had not been presented at study. Each of the five recognition tests used a different set of unrelated lures. Six of the unrelated lures were related lures for six Roediger and McDermott (1995) or Stadler et al. (1999) lists that were not presented to a particular participant (thus, for example, for a participant who was never exposed to the list of words including *cigarette, puff, blaze, billows, pollution, ashes, cigar,* and so forth, *smoke* constituted an unrelated lure word). The other six unrelated lures were taken from Position 6 of the lists to which the participant had not been exposed (e.g., *ashes*). No unrelated lures were repeated. Analyses of false-alarm rates to these two different types of unrelated lures indicated no significant differences between them ($F = 2.42$, $p = .129$), so the two types of unrelated lures were treated as a single category in all experimental analyses.

Test words were presented visually in the same font and size at study and test and were shown until the participant responded verbally with an "old" or "new" response. The experimenter then entered the appropriate response on the keyboard.

Results

Table 1 lists the demographic data, the results of the standard neuropsychological tests, and the statistical comparisons between the mild-to-moderate AD patients versus older adults, and older adults versus young adults. Not surprisingly, AD patients performed significantly worse than healthy older adults on word fluency to letters and categories, as well as in both subtests of the BDS. No differences were seen between young and older adults in letter and category word fluency or the BDS-IMC; there was a marginally significant difference on the BDS-AHP (mainly due to many older adults reporting that they were currently somewhat sadder than they used to be).

Table 2 shows the proportions of "old" responses to (a) previously studied words, (b) related lures that are semantic associates of previously studied words, and (c) unrelated lures that are not associates of previously studied words. Figure 1 displays corrected true and false recognition obtained by subtracting the proportion of "old" responses to unrelated lures from the proportion of "old" responses to studied words and related lures, respectively. In addition to within-group comparisons, AD patients were compared with older adults. Comparisons of older adults to young adults were performed but revealed no significant differences between these groups. (AD patients were not directly compared to young adults because it is not clear what this comparison would represent.) After these analyses of overall recognition performance, we present signal detection analyses that provide estimates of sensitivity (A′) and bias (B_D'') for several key comparisons (see Table 3).

Table 2
True Recognition of Studied Words, False Recognition of Related Lures, and False Recognition of Unrelated Lures in Alzheimer's Disease (AD) Patients, Younger Adults, and Older Adults

Trial	AD	*SD*	Older	*SD*	Younger	*SD*
True recognition of studied words						
1	0.66	0.31	0.73	0.18	0.84	0.14
2	0.79	0.23	0.91	0.11	0.95	0.07
3	0.86	0.17	0.92	0.12	0.97	0.06
4	0.84	0.23	0.93	0.14	0.98	0.05
5	0.89	0.14	0.94	0.13	0.99	0.02
False recognition of related lures						
1	0.69	0.30	0.67	0.28	0.68	0.31
2	0.88	0.21	0.67	0.25	0.64	0.33
3	0.86	0.17	0.69	0.14	0.54	0.29
4	0.83	0.21	0.57	0.27	0.46	0.29
5	0.88	0.16	0.50	0.24	0.42	0.26
False recognition of unrelated lures						
1	0.28	0.24	0.04	0.05	0.03	0.04
2	0.28	0.24	0.01	0.03	<0.01	0.02
3	0.19	0.21	0.01	0.03	0.02	0.05
4	0.17	0.18	<0.01	0.02	<0.01	0.02
5	0.18	0.31	<0.01	0.02	<0.01	0.01

True Recognition

Consider first analyses of the initial test trial (see Table 2). AD patients made numerically but not significantly fewer "old" responses to studied words than did older adults (.66 vs. .73, $F < 1$). In addition, AD patients made significantly more "old" responses to unrelated lures than did older adults (.28 vs. .04); $F(1, 22) = 10.85$, $MSE = 0.334$, $p = .003$. Analyses of corrected recognition scores that were obtained by subtracting the proportion of "old" responses to unrelated lures from the proportion of "old" responses to studied words (see Figure 1A) revealed that AD patients exhibited significantly reduced levels of recognition accuracy compared with healthy older adults (.38 vs. .69), $F(1, 22) = 16.97$, $MSE = 0.560$, $p < .001$.

Consideration of all five test trials indicates that true recognition was affected similarly by study–test repetitions in all groups (see Table 2 and Figure 1A). Repetition of study–test trials produced a consistent increase in the proportion of "old" responses to studied words made by young and older adults as well as AD patients. An analysis of variance (ANOVA) on these responses that included group

as a between-subjects variable and trials as a within-subject variable showed highly significant effects of trial between AD patients and older adults, $F(4, 88) = 18.33$, $MSE = 0.329$, $p < .001$; there was no effect of group ($F = 1.32$) and no Group × Trial interaction ($Fs < 1$).

The proportion of "old" responses to unrelated lures decreased numerically but not significantly across trials in all groups when each group was analyzed individually ($Fs < 2$, $ps > .15$; note that floor effects were operative for controls; see Table 2). An ANOVA for the AD versus older adult comparison yielded a trend for main effect of trial, $F(4, 88) = 2.59$, $MSE = 0.050$, $p = .083$, a significant effect of group, $F(1, 22) = 11.37$, $MSE = 1.22$, $p = .003$, and a nonsignificant Group × Trial interaction ($F = 1.24$). Analyses of corrected recognition scores for the AD versus older adult comparison showed main effects of group, $F(1, 22) = 16.55$, $MSE = 2.32$, $p = .001$, and trial $F(4, 88) = 24.14$, $MSE = .377$, $p < .001$, but no Group × Trial interaction, $F(4, 88) = 2.07$, $p = .103$.

False Recognition

Considering the data from the first trial, there was no difference in the number of old responses to related lures (the theme words) between any of the groups ($Fs < 1$; see Table 2). The AD patients, however, showed significantly reduced levels of corrected false recognition (obtained by subtracting the proportion of "old" responses to unrelated lures from the proportion of "old" responses to related lures) compared with the older adults, (.42 vs. .63); $F(1, 22) = 4.41$, $MSE = 0.260$, $p = .047$ (see Figure 1B). Thus, the overall pattern of the first trial data comparing AD patients to older adults is generally consistent with the previous findings of reduced false recognition in amnesic patients (Schacter, Verfaellie, & Anes, 1997; Schacter, Verfaellie, et al., 1998; Schacter, Verfaellie, & Pradere, 1996) and patients with AD (Balota et al., 1999).

Consideration of all five test trials (see Table 2 and Figure 1B) reveals that different patterns of false recognition emerged in the three groups. AD patients showed increasing levels of false recognition across trials that closely paralleled their increase in true recognition. An ANOVA performed on the false-recognition data for this group alone that included trial as a within-subject variable showed a marginally significant effect of trial, $F(4, 11) = 2.96$, $MSE = 0.113$, $p = .059$. The corrected false-recognition data (see Figure 1B) showed steadily increasing false recognition, and an ANOVA revealed a significant effect of trial, $F(4, 11) = 4.36$, $MSE = 0.251$, $p = .017$. Comparing true and false recognition directly in AD patients, using an ANOVA that included trial as a within-subject variable and recognition type as a between-subjects variable, we found a significant effect of trial (uncorrected and corrected: $Fs > 5.83$, $ps < .012$), no effect of type ($F < 1$), and no Type × Trials interaction ($F = 1.07$).

The young adults showed steadily decreasing levels of

Table 3
Signal Detection Analyses of Sensitivity (A') and Bias (B_D'') as a Function of Study–Test Trials in Patients With Alzheimer's Disease (AD), Older Adults, and Younger Adults

	AD		Older		Younger	
Trial	A'	B_D''	A'	B_D''	A'	B_D''
Item-specific recollection (hits vs. unrelated-lure false alarms)						
1	0.77	−0.05	0.90	0.54	0.93	0.33
2	0.83	−0.12	0.95	0.23	0.97	0.12
3	0.89	−0.11	0.96	0.14	0.97	−0.12
4	0.88	−0.07	0.96	0.07	0.98	−0.11
5	0.89	−0.02	0.96	0.10	0.98	−0.15
Item-specific recollection (hits vs. related-lure false alarms)						
1	0.50	−0.23	0.56	−0.35	0.65	−0.48
2	0.44	−0.38	0.73	−0.79	0.74	−0.67
3	0.56	−0.70	0.73	−0.83	0.82	−0.84
4	0.56	−0.65	0.79	−0.76	0.85	−0.83
5	0.58	−0.59	0.82	−0.78	0.87	−0.87
Gist memory (related- vs. unrelated-lure false alarms)						
1	0.79	−0.03	0.87	0.62	0.87	0.57
2	0.86	−0.25	0.88	0.75	0.87	0.71
3	0.88	−0.01	0.89	0.77	0.83	0.83
4	0.87	0.10	0.86	0.81	0.82	0.90
5	0.86	0.19	0.84	0.86	0.81	0.90

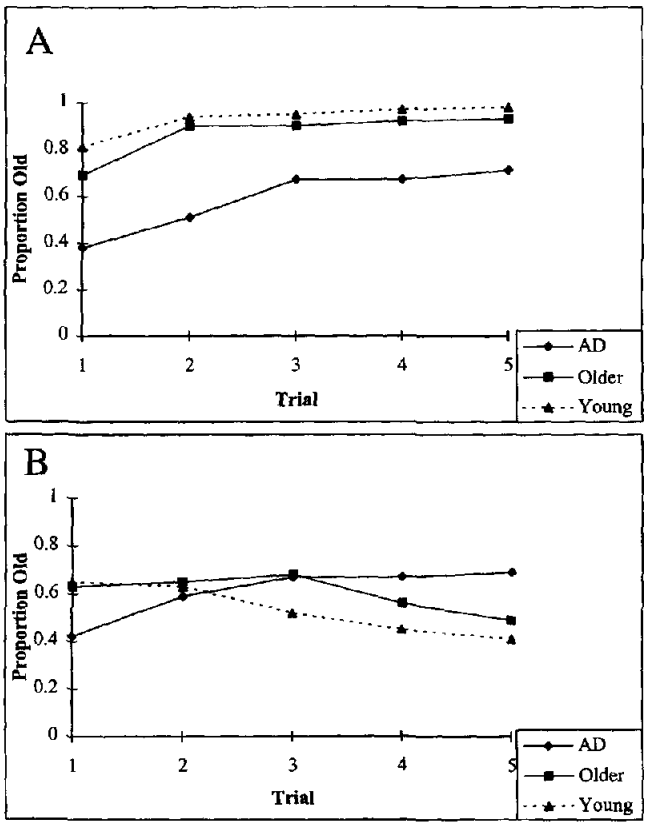

Figure 1. Corrected true and false recognition obtained by subtracting the proportion of "old" responses to unrelated lures from the proportion of "old" responses to studied words (A) and related lures (B) in patients with Alzheimer's disease (AD), older adults, and younger adults as a function of study–test trial.

false recognition across trials, uncorrected: $F(4, 11) = 5.54$, $MSE = 0.317$, $p = .012$; corrected: $F(4, 11) = 4.33$, $MSE = 0.252$, $p = .024$. Not surprisingly, because their true recognition steadily increased while their false recognition steadily decreased, comparisons between true and false recognition in young adults yielded nonsignificant effects of trial (uncorrected and corrected: $Fs < 1.6$, $ps > .23$) and highly significant effects of recognition type ($Fs > 27$, $ps < .001$) and of the Type × Trials interaction ($Fs > 14.5$, $ps < .001$).

Older adults showed significantly lower levels of false recognition on the final trial versus the initial one: uncorrected, .67 versus .50, $t(11) = 2.71$, $MSE = 0.062$, $p = .020$; corrected, .63 versus .49, $t(11) = 2.22$, $MSE = 0.059$, $p = .048$. Across all five trials, however, their false recognition fluctuated, as reflected by an ANOVA that demonstrated only a trend toward decreasing levels of false recognition, uncorrected: $F(4, 11) = 2.53$, $MSE = 0.133$, $p = .089$; this trend did not hold when false recognition was corrected for false alarms to unrelated lures, $F(4, 11) = 2.19$, $MSE = 0.103$, $p = .117$. Comparisons between true and false recognition in older adults showed highly significant effects of recognition type, $F(1, 11) = 30.81$, $MSE = 2.10$, $p < .001$, and of the Type × Trials interaction, $F(4, 44) = 9.27$, $MSE = 0.151$, $p < .001$, and either a nonsignificant effect of trials, uncorrected: $F(4, 44) = 1.89$, $p = .176$, or a trend, corrected: $F(4, 44) = 2.79$, $MSE = 0.117$, $p = .073$. Thus, although their pattern of false recognition demonstrated some fluctuations, older adults clearly exhibited different patterns of true and false recognition.

Comparing the false recognition of AD patients to that of the older adults showed significant Group × Trial interactions for uncorrected, $F(1, 88) = 3.53$, $MSE = 0.118$, $p = .016$, and corrected, $F(1, 88) = 4.39$, $MSE = 0.176$, $p = .005$, false recognition responses, resulting in a crossover interaction of the corrected data (see Figure 1B). An effect of group was seen with the uncorrected data, $F(1, 22) = 8.71$, $MSE = 1.30$, $p = .007$, but not the corrected data ($F < 1$). Thus, the overall pattern across trials comparing AD patients with older adults is generally consistent with that observed in Korsakoff amnesic patients compared with controls (Schacter, Verfaellie, et al., 1998) and with the matched group data in the study of AD by Balota et al. (1999).

Signal Detection Analyses

To determine whether the main findings of the experiment are attributable to changes in sensitivity or response bias, we performed signal detection analyses that have been described and applied to similar kinds of true versus false recognition data by Koutstaal and Schacter (1997), Schacter, Verfaellie, et al. (1998), and Tussing and Greene (1997), using A′ as an estimate of sensitivity and B_D'' as an estimate of response bias (Donaldson, 1993; Snodgrass & Corwin, 1988). Values of A′ can vary between 0 and 1; higher values indicate greater sensitivity, with 0.5 indicating chance performance. Values of the bias measure, B_D'' can vary between −1 (indicating extremely liberal responding) and +1 (indicating extremely conservative responding). Because these measures are undefined, with true recognition (or hit) rates of 0 or 1, the data were first transformed, as recommended by Snodgrass and Corwin (1988), by computing $p(x)$ as $(x + 0.5)/n + 1$ rather than as x/n. In addition, when individual participants showed below-chance sensitivity (hits < false alarms, or A′ < 0.50), modified formulas provided by Aaronson and Watts (1987) were used.

Following the methodology of Koutstaal and Schacter (1997), we provide three different types of signal detection analyses, shown in the upper, middle, and lower sections of Table 3. The uppermost section shows estimates of sensitivity and bias comparing hits (i.e., "old" responses to studied items) with false alarms to unrelated lures, which constitutes a measure of item-specific true recognition (referred to as A′ unrelated and B_D'' unrelated for sensitivity and bias, respectively). The middle section compares hits with false alarms to related lures, which provides a different measure of item-specific true recognition (A′ related and B_D'' related for sensitivity and bias, respectively). In the bottom section, false alarms to related lures are depicted as a form of memory for the gist of the study list (cf., Brainerd, Reyna, & Kneer, 1995; Koutstaal & Schacter, 1997) and thus are treated in the same manner as hits in the previous two analyses. For this analysis, false alarms to related lures are compared with false alarms to unrelated lures; A′ indicates the extent to which participants called related lures "old," compared with how often they called unrelated lures "old." We call these measures of sensitivity and bias A′ gist and B_D'' gist, respectively.

Item-specific recollection (hits compared with unrelated-lure false alarms). Table 3 shows that A′ unrelated increased across trials for groups, reaching near-ceiling levels in young and older adults. In addition, as expected, A′ unrelated was consistently higher in older adults than in AD patients: An ANOVA revealed significant main effects of group, $F(1, 22) = 13.20$, $MSE = 0.274$, $p = .001$, and trial, $F(4, 88) = 13.41$, $MSE = 0.064$, $p < .001$, along with a nonsignificant effect of Group × Trial ($F = 1.93$).

Table 3 shows that the bias measure, B_D'' unrelated, decreased significantly in older and young adults, effect of trial: $F(4, 88) = 10.79$, $MSE = 1.23$, $p < .001$, indicating a significant trend toward more liberal responding, but it remained constant in the AD patients. Comparisons of AD patients versus older adults failed to reveal significant effects of group, trial, or Group × Trial ($Fs < 2.5$).

Item-specific recollection (hits compared with related-lure false alarms). The A′-related values in the middle panel of Table 3 reflect the extent to which participants distinguished between studied words and related lures. On the first trial, there was no significant difference in this measure between AD patients and older adults ($F < 1$); all groups performed relatively close to chance. However, whereas the older and young adults showed similar patterns of increasing A′ related across trials, AD patients did not change significantly: their ability to distinguish between studied items and related false lures remained at near chance levels of performance. An ANOVA focusing on the AD patients alone showed a nonsignificant effect of trials, $F(4, 44) = 2.26$, $p = .104$, whereas comparisons between AD

patients and older adults revealed significant effects of trials, $F(4, 88) = 9.03$, $MSE = .148$, $p < .001$, group, $F(1, 22) = 25.38$, $MSE = 1.21$, $p < .001$, and Group × Trials, $F(1, 88) = 3.80$, $MSE = .062$, $p = .013$. Taken together, these data indicate that young and older adults improved in their ability to distinguish between studied words and related lures across trials, whereas AD patients did not.

The B_D'' related values shown in the middle section of Table 3 indicate that when "old" responses to related lures are treated as false alarms, all groups responded quite liberally and exhibited a tendency to respond more liberally across trials. ANOVAs comparing AD patients versus older adults showed significant effects of trial, $F(4, 88) = 7.90$, $p < .001$, and nonsignificant effects of group, $F(1, 22) = 2.64$, $p = .118$, and Group × Trials ($F < 1$).

Gist memory (related-lure false alarms compared with unrelated-lure false alarms). A′ gist, shown in the lower panel of Table 3, does not necessarily indicate the amount of gist memory available to participants, but rather reflects their tendency to rely on gist despite any opposing influence of item-specific memory. On the first trial, AD patients showed significantly lower A′ gist than did older adults (.79 vs. .87), $F(1, 22) = 6.40$, $MSE = .040$, $p = .019$. Examining A′ gist in the AD patients across trials reveals a rise between the first and third trials, followed by a plateau during the fourth and fifth trials. This analysis is supported by ANOVAs of the AD patients that revealed no significant effects across all trials, $F(4, 44) = 2.04$, $p = .153$, but did show a significant effect of trials over Trials 1–3 $F(2, 22) = 5.82$, $MSE = .039$, $p = .023$, compared with no change over Trials 3–5, $F(2, 22) < 0.10$. A′ gist did not change significantly across trials in older adults; an ANOVA revealed a nonsignificant effect of trials, ($F = 1.7$). A′ gist decreased across trials in young adults, as indicated by a marginally significant effect of trials, $F(4, 44) = 3.18$, $MSE = .019$, $p = .057$. Comparisons between A′ gist in AD patients versus older adults showed nonsignificant effects of group ($F < 1$), trials ($F = 1.97$), and Trials × Group ($F = 1.95$).

As shown in the lower panel of Table 3, B_D'' gist was significantly lower in AD patients than in older adults, group effect: $F(1, 22) = 17.53$, $MSE = 17.31$, $p < .001$, indicating more liberal responding in the AD patients. Both groups increased their B_D'' gist across trials, $F(4, 88) = 4.92$, $MSE = .399$, $p = .004$, suggesting progressively more conservative responding. There was also a nonsignificant Group × Trials interaction, $F(1, 88) = 2.20$, $p = .108$.

Discussion

Previous research has shown that AD patients exhibit lower levels of false recognition than healthy older adults overall, but greater false recognition than older adults in a subset of participants who were selected on the basis of showing similar levels of true recognition (Balota et al., 1999). The present study confirmed and extended this earlier work by demonstrating that, compared with older adults, AD patients show lower levels of false recognition after a single exposure to a list of semantic associates and higher levels of false recognition after multiple exposures to the study list. In addition, we related our research to previous work with amnesic patients by demonstrating that AD patients show an increase in false recognition across trials similar to that of Korsakoff amnesic patients.

Analysis of the first trial reveals that, compared with older adults, AD patients made significantly more false alarms to unrelated lures, and, consequently, their corrected true recognition was impaired. Patients with AD also showed decreased levels of corrected false recognition of related lures compared with older adults, consistent with previous work in AD (Balota et al., 1999) and with data from amnesia studies (Schacter, Verfaellie, & Anes, 1997; Schacter, Verfaellie, & Pradere, 1996; Schacter, Verfaellie, et al., 1998).

Across trials, true recognition of studied words increased in all groups, indicating that patients with mild-to-moderate AD are able to increase their true recognition of words by repeated presentations of the study list. False recognition of unrelated lures decreased numerically, but not significantly, in all groups. Of particular interest is the finding that, although there were similar patterns of true recognition and false recognition of unrelated lures across trials in AD patients, young adults, and older adults, these groups were characterized by different patterns of false recognition of related lures. AD patients showed increasing levels of false recognition of related lures across trials, a pattern observed in Korsakoff amnesic patients but not in those with mixed medial temporal amnesia (Schacter, Verfaellie, et al., 1998). Young adults showed steadily decreasing levels of false recognition of related lures, results that were similar to those found by Kensinger and Schacter (1999). Older adults showed a level of false recognition that was in between that of AD patients and young adults: lower false recognition on the final trial compared with the initial one, although across all five trials their false recognition exhibited a somewhat fluctuating pattern (cf. Kensinger & Schacter, 1999). Significant differences were observed in false recognition of related lures between AD patients and older adults, resulting in a crossover interaction when the data were corrected for false alarms to unrelated lures.

The lower level of corrected false recognition seen in the initial trial for AD patients compared with older adults suggests that AD patients were initially less sensitive to gist influences than were older adults. In addition, signal detection analyses suggest that, compared with AD patients, older adults used significantly more conservative response criteria when distinguishing between related and unrelated lures (see Table 3, B_D'' gist). Thus, although the influence of gist in AD patients (as measured by corrected false recognition and A′ gist) quickly rose to the level of older adults in the second and third trials and responses of both groups became more conservative across trials, older adults continued to use much more conservative response criteria than did AD patients. In the analysis of item-specific recollection (see Table 3, A′ related), both groups initially performed close to chance in their ability to distinguish studied items versus related lures. However, older adults showed increasing sensitivity to the distinction between studied items and related lures, whereas the AD patients remained at near chance levels of performance.

As Schacter, Verfaellie, et al. (1998) suggested for their Korsakoff amnesic patients, the increasing sensitivity to gist influences seen in our AD patients indicates that repeated study and testing of semantic associates creates an increasingly robust representation of semantic gist that, when unchecked by item-specific recollection, produces increasingly elevated levels of false recognition. Repeated study and testing also presumably leads to an increasingly robust gist representation in young and older adults, but they can make use of explicit recollection to employ increasingly conservative response criteria and greater sensitivity to item-specific recollection that serve to counteract or suppress the strengthening gist representation. Our results suggest that, in this study AD patients predominantly used memory for gist information, which allowed them to show significant increases in their true recognition across trials and at the same time made them incapable of distinguishing between studied items and semantically associated related lures. This hypothesis is supported by the within-group analysis that found no difference between true recognition of studied words and false recognition of related lures across trials in AD patients.

The fact that AD patients exhibit a false-recognition pattern similar to persons with Korsakoff amnesia and different from those with non-Korsakoff amnesia could suggest that even mild-to-moderate AD patients have dysfunction of frontal networks, as Korsakoff amnesic patients are known to have (cf. Moscovitch, 1982; Schacter, 1987; Shimamura, 1995; Squire, 1982), sufficient to contribute to AD patients' severely impaired ability to suppress the strengthening across-trial influence of semantic gist. AD patients do show pathologic changes in frontal lobes at autopsy (Lidstrom et al., 1998) and neuropsychological and neuroimaging studies of AD patients have demonstrated frontal lobe dysfunction (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Dalla Barba, Nedjam, & Dubois, 1999; Haxby et al., 1988; Mountjoy, Roth, Evans, & Evans, 1983). Consistent with this possibility and as previously articulated in Schacter, Verfaellie, et al. (1998), damage to the frontal lobes has been linked with high levels of false recognition (Parkin, Bindschaedler, Harsent, & Metzler, 1996; Schacter, Curran, Galluccio, Milberg, & Bates, 1996). Moreover, a number of neuroimaging studies have strongly implicated various regions within the frontal lobes in episodic memory (cf., Buckner et al., 1995; Nyberg et al., 1995; Schacter, Alpert, Savage, Rauch, & Albert, 1996; Shallice et al., 1994; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). In addition, anterior prefrontal regions may be specifically related to post-retrieval monitoring and verification processes (Rugg, Fletcher, Firth, Frackowiak, & Dolan, 1996; Schacter, Buckner, Koutstaal, Dale, & Rosen, et al., 1997; Schacter, Reiman, et al., 1996; Wilding & Rugg, 1996). Such processes, which may be related to the inhibitory functions of the frontal lobes (Shimamura, 1995), would presumably be required in order to use item-specific recollection information to suppress false recognition and may be relatively impaired in AD patients compared with healthy older adults.

As in Korsakoff amnesic patients, deficits in frontal lobe function linked to source memory confusion could also be implicated in the impaired ability of AD patients to suppress false recognition. This type of source memory confusion is frequently reported in individuals with frontal lobe dysfunction (Janowsky, Shimamura, & Squire, 1989; Schacter, Harbluk, & McLachlan, 1984). AD patients are known to show deficits in source memory in addition to their executive function deficits, as reported most recently by Dalla Barba et al. (1999). Because our paradigm consists of repeated presentations and tests across trials, the ability to discriminate studied items from related lures necessitates identification of their source. Both studied items and related lures would have been encountered on later trials; related lures would only have been present on earlier test lists, whereas studied items would have been present on both study and test lists. It may be that AD patients had particular difficulty in remembering whether an item had been presented on a study or test list.

One feature of our results, however, suggests that source memory is not of critical importance for suppression of false recognition in our paradigm. If older adults used intact source memory abilities to suppress false recognition by recollecting correctly that they encountered related lures on prior tests and not on study lists, then suppression of false recognition should have been expressed primarily by significant changes in their corrected false recognition across trials; that is, older adults should have been able to selectively reduce "old" responses to related lures. Although our young adults did show steadily decreasing levels of corrected false recognition across trials, the older adults did not. Our data on older adults indicate that suppression occurred mainly through the use of a more conservative criterion, perhaps reflecting intact verification processes or inhibitory functions. Future studies could examine the roles of verification–inhibition mechanisms on the one hand and study–test-source confusions on the other, with a modified paradigm in which repeatedly studied sets of semantic associates and their related lure words are not tested repeatedly; estimates of first-trial performance could be obtained on a different set of items that is not presented again for study or for test. If impaired verification–inhibition mechanisms are responsible for the effects we observed in AD patients, then AD patients should show the same pattern of increasing false recognition observed in the present study; if the effects we observed are attributable to source confusions, then AD patients should not show increasing false recognition of related lures in the modified paradigm.

It may be, as argued above, that for AD patients both true and false recognition in the Deese/Roediger–McDermott paradigm is based largely or entirely on a degraded representation of semantic gist of the study list and that the item-specific recollection of AD patients is simply too impoverished to support suppression of false recognition. If this were the case, then frontal lobe dysfunction need not be implicated in explaining the severe inability of AD patients to suppress their false recognition. Thus, in addition to possible source memory confusion and impaired verification–inhibition mechanisms due to frontal lobe dysfunction, another possible explanation for the pattern of false recogni-

tion observed in AD patients is impaired episodic memory due to medial temporal lobe dysfunction alone.

Deficits in semantic memory may also help explain the false-recognition results observed in our AD patients. Looking at intrusions in AD using the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987), Simon, Leach, Winocur, & Moscovitch (1994) found that although AD patients showed deficits in their ability to cluster words by taxonomic category at recall, this ability did improve over trials, though never to the level of controls. Several investigators (Chertkow, Bub, & Seidenberg, 1989; Martin & Fedio, 1983) found that, although AD patients were very impaired on questions about an object's attributes (e.g., when shown a saw they had great difficulty answering the question, "Is it used for cutting?"), they were less impaired in answering questions about its category membership (e.g., "Is it a tool?"). Grober, Buschke, Kawas, & Fuld, (1985) found that AD patients were 95% accurate on a task that required them to check off attributes that were related to a target concept (e.g., the word *airplane*). Certainly one of the most robust findings in AD patients is that they show difficulty in generating specific items in a given semantic category (Monsch et al., 1992), as was the case in our study (Table 1). In fact, on the supermarket fluency task, Troster, Salmon, McCullough, and Butters (1989) found that AD patients were more likely to produce a high proportion of category names (e.g., *fruit, vegetable*) relative to names of specific items. If AD patients had difficulty encoding items as distinct units, secondary to pathology in the lateral and ventral temporal cortex (Price & Morris, 1999), and instead encoded only the category that the individual items belonged to, this would provide another explanation as to why AD patients developed gist but not item-specific recollection. Whether due to semantic memory dysfunction, episodic memory dysfunction, frontal lobe dysfunction, or some combination of these deficits, AD patients were able to develop gist memory but not the item-specific recollection necessary to suppress false recognition across trials.

Finally, this study suggests two clinically relevant points. First, in contrast to neuropsychology textbooks reporting that the memory of AD patients does not benefit from repetition or from conceptual relationships such as semantic categories and gist (Lezak, 1995), we have shown that, although mild-to-moderate AD patients exhibit impaired item-specific recollection, their memory for gist information can improve with repeated item presentation. Although this gist memory of AD patients is somewhat degraded, it may be the only kind of episodic memory they exhibit. Therefore, when trying to teach new information to a patient with mild-to-moderate AD, it is reasonable to expect that with repeated trials they may be able to learn the gist of the information. However, it may be unrealistic to expect that they will develop detailed item-specific recollection, regardless of the amount of repetition. Second, because item-specific recollection—the ability to distinguish studied words from semantically related associates—proved to be a robust difference between patients with AD and older adults in our study, clinical tests that are able to measure this type of item-specific recollection may prove to be most useful in distinguishing early AD from the effects of normal aging.

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