

# Overdependence on Degraded Gist Memory in Alzheimer's Disease

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Alzheimer's disease (AD) reduces associative effects on false recognition in the Deese–Roediger–McDermott task, either due to impaired memory for gist or impaired use of gist in memory decisions. Gist processes were manipulated by blocking or mixing studied words according to their associations and by varying the associative strength between studied and nonstudied words at test. Both associative blocking and associative strength had smaller effects on false recognition in AD patients than in control participants, consistent with gist memory impairments. However, unlike the case with control participants, blocking influenced true and false recognition equally in AD patients, demonstrating an overdependence on gist when making memory decisions. AD also impaired item-specific recollections, relative to control participants, as true recognition of studied words was reduced even when the two groups were equated on gist-based false recognition. We propose that the overdependence on degraded gist memory in AD is caused by even larger impairments in item-specific recollections.

*Keywords:* false recognition, Alzheimer's disease, gist, list blocking

The early stages of Alzheimer's disease (AD) are characterized by a variety of cognitive impairments that can be detected even before clinical diagnosis, including declines in episodic memory or the ability to recollect specific information about personally experienced events (Bäckman, Jones, Berger, Laukka, & Small, 2005). In addition to impairing memory for studied events (true memory), AD leaves individuals more prone to false memories, or the erroneous belief that new events were studied earlier. Increased false recall or false recognition in AD has been found in a variety of laboratory tasks (e.g., Dalla Barba & Wong, 1995; Gallo, Sullivan, Daffner, Schacter, & Budson, 2004; Knight, 1998) as

well as in measures of nonlaboratory or autobiographical memory accuracy (e.g., Budson et al., 2004). These elevated errors suggest that AD impairs retrieval monitoring processes, or the ability to use recollection to strategically regulate the accuracy of memory retrieval (e.g., Koriat, Goldsmith, & Pansky, 2000).

Much of the laboratory research on memory distortions has used the Deese–Roediger–McDermott (DRM) false memory task (see Gallo, in press, for a comprehensive review). In this task, participants study lists of words (e.g., *bed, rest, awake...*) that are associated with a nonstudied but related lure (e.g., *sleep*). On the basis of these associative relationships, participants are more likely to falsely recognize these related lures (e.g., *sleep*), relative to unrelated lures (e.g., *tiger*), as having occurred in the study list. Associations are thought to cause this false recognition effect by directly activating the related lure from memory, and/or by causing participants to encode an organized theme or gist representation of the list that subsequently makes the related lure feel more familiar. Although there are important differences between these theories (e.g., Brainerd & Reyna, 2005; Gallo & Roediger, 2002), because they make similar predictions for the current study, we presently use the term “*gist*” in the DRM task to refer to the combined influence of associative and semantic processes on false recognition.

In studies using the DRM task, it often is found that the relative proportion of false memories to true memories is greater in AD patients in comparison with healthy control participants (e.g., Balota et al., 1999; Watson, Balota, & Sergent-Marshall, 2001). However, an absolute increase in the occurrence of false memories in AD patients is not always obtained, and the effects of gist on false recognition are often smaller in patients than in controls. This

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This research was supported by National Institute on Aging Grants AG021369 to David A. Gallo, R01 AG025815 and P30 AG13846 to Andrew E. Budson, and AG08441 to Daniel L. Schacter, as well as a Brigham and Women's Hospital Faculty Award in Translational Neurosciences to Andrew E. Budson.

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pattern has been demonstrated in several studies using the DRM task (Budson, Sitariski, et al., 2002; Budson, Sullivan, et al., 2002; Waldie & Kwong See, 2003). It also has been demonstrated in studies using other types of materials, including phonologically related words (Budson, Sullivan, Daffner, & Schacter, 2003), categorized pictures (Budson, Michalska, et al., 2003), and perceptually similar abstract shapes (Budson, Desikan, Daffner, & Schacter, 2001). Because these different tasks rely on different types of gist to elicit false recognition, they implicate a fundamental deficit in gist processing in AD.

The reduced influence of gist on false recognition in AD patients is firmly established, but the locus of this effect is unclear. Deficits in the processing of semantic or associative information in AD (e.g., Chan et al., 1993; Hodges & Patterson, 1995) implicate difficulties in the extraction of gist during the study phase, especially in the DRM task, and deficits in episodic memory implicate difficulties in the encoding (and retrieval) of this gist information. These explanations assume that memory for gist information is impaired by AD, much as gist memory seems to be impaired by damage to medial temporal regions in other types of amnesia (e.g., Verfaellie, Schacter, & Cook, 2002). Alternatively, deficits in strategic retrieval processes might be involved. It has been argued that healthy older adults are more likely than younger adults to strategically rely on gist information to guide their retrieval decisions, in order to compensate for age-related deficits in item-specific recollections (e.g., Koutstaal, Schacter, Galluccio, & Stofer, 1999; Tun, Wingfield, Rosen, & Blanchard, 1998). If AD impairs these strategic processes, then AD patients would be less likely to make gist-based inferences relative to healthy older adults. This strategic deficit could explain the observed reduction in gist-based false recognition in AD, relative to healthy older adults, in addition to (or instead of) an inability to remember gist information. Because prior work has not directly manipulated gist processing in AD, these two possibilities cannot be teased apart.

One manipulation that has been shown to affect gist processing in the DRM task is whether the study lists are blocked or mixed by associated themes (e.g., participants study all of the associates to “sleep” in one list, and all of those to “rough” in another, or each list contains words associated with multiple themes). Numerous studies with younger adults have found that blocked presentation leads to greater levels of false recall or false recognition of related lures than does mixed presentation (Brainerd, Payne, Wright, & Reyna, 2003; Mather, Henkel, & Johnson, 1997; McDermott, 1996; Toggia, Neuschatz, & Goodwin, 1999; Tussing & Greene, 1997), most likely because blocking facilitates the encoding of the common associations or gist between studied words and related lures. Importantly, blocking enhances illusory recollection, or the subjective experience that one is actually “remembering” the occurrence of the nonstudied lure in the study list (Brainerd et al., 2003; Mather et al., 1997). This effect suggests that blocking influences the more automatic or unavoidable influences of gist memory, as opposed to more inferential or strategic guessing processes that should not elicit a strong sense of illusory recollection. In contrast, true memory for list words was not affected by blocking in these studies (e.g., Tussing & Greene, 1997), or the blocking effect on true memory was smaller than that found on false memory (e.g., Toggia et al., 1999). Although list words are related to each other, and thus could be affected by blocking, true memory also can be based on item-specific recollections. By

definition, item-specific recollections are unique to each studied word, and thus the associative context at study is less critical for these sorts of recollections as it is for gist information (see Brainerd et al., 2003).

In the present study, we used the blocking manipulation to further investigate the reduced effects of gist on false recognition in AD. On the basis of prior work, we expected to find a blocking effect on false recognition of related lures in control participants, but whether AD patients would show a similar blocking effect was unknown. If AD primarily impairs gist memory, then the external organization of associative themes should not matter as much for AD patients as it would for controls. AD patients would have difficulty remembering the gist in either the blocked or mixed conditions, resulting in larger blocking effects in controls. This prediction also follows from a recent developmental finding by Lampinen, Leding, Reed, and Odegard (2006). In that study, it was found that DRM blocking effects were smaller in young children compared with older children, and it was argued that young children have difficulty processing the gist of the lists. If similar difficulties were prevalent in AD, then we would expect similar results. In contrast, if AD patients simply are less likely than healthy older adults to strategically rely on gist information at retrieval, and gist memory is spared, then similar-sized blocking effects might be found in AD patients and control participants. This prediction is based on the assumption that blocking effects primarily are due to the automatic influences of gist memory on false recognition.

As an additional test of the idea that AD impairs gist memory, we manipulated the associative strength between studied and nonstudied words (i.e., the average probability that each word in a list would elicit the nonstudied word on a free association test). Prior work has demonstrated that strong associates are more likely to be falsely recognized than weak associates (e.g., Roediger, Watson, McDermott, & Gallo, 2001), owing to differences in associative activation and/or gist-based processes. Much like blocking effects, associative strength influences the subjective experience of illusory recollection (e.g., Brainerd et al., 2003; Gallo & Roediger, 2002), and the effects of associative strength are smaller in children than in adults (Brainerd, Reyna, & Forrest, 2002). However, the manipulation of associative strength is less obvious to subjects than associative blocking, and for the present study we used strong and weak associates that both seemed related to the gist of the list (e.g., *foot* and *knee* were the strong and weak associates for the list: *shoe, hand, toes, kick, sandals, heel, leg, walk, ankle, arm, boot, sneaker*; in a second example, *bread* and *loaf* were the corresponding associates for the list: *butter, stale, crumb, sandwich, rye, jam, wheat, flour, rolls, dough, crust, bun*). If the critical difference between AD patients and control subjects is the strategic use of gist at test, then one might not expect group differences in the effects of this associative manipulation (if anything, controls would be less sensitive to subtle differences in associative strength, because they would be more likely than patients to endorse any item that seemed to “fit the gist”). In contrast, if AD causes a more fundamental deficit in memory for the associative themes or gist of the lists, then false recognition in AD patients should be less sensitive to differences in associative strength.

A final comparison of interest was the relative influence of associative blocking on true and false recognition within each group. Based on prior studies, we expected a smaller blocking

effect on true recognition than false recognition in control subjects. As discussed, this pattern suggests that participants are less influenced by gist information when correctly recognizing studied words, relative to related lures. If AD patients were less likely than controls to strategically rely on gist information, then one might expect even smaller effects of blocking on list words in AD patients. Conversely, if AD patients were more likely than controls to rely on gist to make memory decisions, then one might expect to find similar-sized blocking effects for list words and related lures in patients. Because the list words were associated with each other, responding mostly on the basis of gist should yield relatively larger blocking effects for these items. This outcome would be expected if item-specific memory were more impaired than gist memory in AD patients, thereby increasing the influence of gist in memory decisions.

## Method

### Participants

Forty-eight patients with clinical diagnosis of probable AD (using NINCDS-ADRDA criteria, McKhann et al., 1984) and 48 healthy controls participated in the experiment, with 24 participants from each group participating in the blocked and the mixed conditions. The AD patients were recruited from the Memory Disorders Unit at Brigham and Women's Hospital (Boston, MA) and The Memory Clinic, Southwestern Vermont Medical Center (Bennington, VT). Age-matched controls were community-dwelling residents of the surrounding areas. The four groups (blocked-controls, mixed-controls, blocked-AD patients, mixed-AD patients) were matched on age (mean age = 76.1, 75.1, 76.5, 77.8 years; range = 65–91 years,  $F(3, 92) < 1$ ), and sex (number of female participants = 13, 15, 12, 14), and all had normal or corrected-to-normal vision and hearing.<sup>1</sup> On average, controls scored higher than AD patients on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975): For control participants,  $M = 29.0$  (range = 26–30), and for AD patients,  $M = 23.35$  (range = 17–30),  $t(94) = 11.94$ ,  $p < .05$ , and had more years of education (14.9 vs. 13.3),  $t(94) = 2.56$ ,  $p < .05$ . More detailed information on the patients' neuropsychological performance can be found in Table 1. Within each participant group, the two experimental conditions did not differ in terms of either of these variables (all  $ps > .05$ ). Participants were excluded on the basis of clinical depression, alcohol or drug use, cerebrovascular disease, traumatic brain damage, or having a primary language other than English. Written informed consent was obtained from all participants and their caregivers (where appropriate), and all participants were paid \$10/hr for their participation. The human subjects committees of Brigham and Women's Hospital, Harvard University, and Southwestern Vermont Medical Center approved the procedures used in this study.

### Materials and Design

The 24 associative lists were based on those published in the Stadler, Roediger, and McDermott (1999) and Gallo and Roediger (2002) norms. The experimenter modified each list to contain the 12 associates that seemed to form the most coherent theme or gist. For counterbalancing, the lists were divided into two sets of 12. Half of the participants in each experimental group studied one set of lists, whereas the other half studied the other set. Items from the nonstudied lists served as unrelated controls on the recognition test. This test contained two words from each of the studied lists (sampled from serial positions 1 and 10), two nonstudied words that were related to each study list (the critical, nonstudied associate to each list and a weaker nonstudied associate), and the corresponding control lures from the 12 nonstudied lists. According to the Nelson, McEvoy, and Schreiber (1998) norms, as well as norms described in

Table 1  
*Neuropsychological Test Data in Patients With Alzheimer's Disease*

Test	<i>M</i>	<i>SD</i>
Overall Cognitive Status		
MMSE	23.35	3.13
Global Deterioration Scale	3.34	0.63
Clock Drawing	5.43	1.64
ADAS Total <sup>a</sup>	13.76	9.88
Memory		
ADAS Memory <sup>a</sup>	8.69	4.42
Intelligence		
Estimated VIQ (Am-NART)	105.56	11.53
Language		
Verbal fluency (animals)	11.16	4.53
ADAS naming 12 objects	11.11	0.78
ADAS naming 5 fingers	4.02	1.12
ADAS objects plus fingers	15.13	1.58
Attention		
Digit span forward	7.52	1.95
Digit span backward	5.16	1.99

*Note.* MMSE = Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975); Global Deterioration Scale (Reisberg, Ferris, de Leon, & Crook, 1982); Clock Drawing (Herrmann et al., 1998); ADAS = Alzheimer's Disease Assessment Scale (Rosen, Mohs, & Davis, 1984); VIQ = Verbal IQ; Am-NART = National Adult Reading Test—American Version (Blair & Spreen, 1989); Verbal Fluency (Monsch et al., 1992); Digit Span (Wechsler, 1997).

<sup>a</sup> Higher scores on ADAS Total and Memory indicate worse performance.

Roediger et al. (2001), the average associative strength (from list words to the lure) was .224 for strong lures and .006 for weak lures,  $t(23) = 13.19$ ,  $SEM = .017$ .<sup>2</sup>

In the blocked condition, each of the 12 study lists was arranged by theme, and the words within each list were presented in descending order of associative strength. In the mixed condition, each list contained one item from each of the 12 themes. Items occurring in the 1st and 10th serial positions in the blocked condition (i.e., those occurring on the subsequent test) also were presented in those positions in the mixed condition (albeit in different lists), whereas the order of the other items was randomly mixed within each list. The order of the study lists was held constant within each counterbalancing condition, but the order of the test words was randomized for each participant.

### Procedure

Participants were instructed that they would study 12 lists and that their job was to read each word aloud and try to remember it for a subsequent memory test. Each study word was presented at the center of the computer screen for 2 s, with no interstimulus interval (black uppercase letters on a white background). After each list of 12 words was presented, a 5-s prompt

<sup>1</sup> Although the groups were not statistically different on age, the control participants were 1.5 years younger than AD patients on average. To check that this age difference did not confound our results, we arbitrarily excluded 4 participants from each experimental condition to numerically match the groups on age ( $M_s = 76.8, 76.7, 76.5$ , and  $76.3$ , respectively). This reduced data set led to a similar pattern of experimental effects and statistical results; thus, analyses of the full data set are reported here.

<sup>2</sup> Normative data were not available for 8 of the 144 possible associations between strong lures and their studied words or for 38 of the possible associations between studied words and weak lures.

appeared in red letters to anticipate the upcoming list (e.g., "List 2"). After all lists had been presented, participants were given instructions for the memory test. They were told that some of the words were studied in one of the lists and that others were not. The participants were instructed to indicate (old vs. new) whether they remembered the word. Test words were presented visually like studied words, and each word remained on the screen until the participant made a response. Participants were asked to take their time to be as accurate as possible (self-paced).

## Results and Discussion

As can be seen in Table 2, the data from the control participants replicated the standard DRM effects (unless otherwise noted, all effects were significant at  $p < .05$ , two-tailed). Recognition of studied words ( $M = .76$ , collapsed across the blocking conditions) was greater than false recognition of the corresponding unrelated lures ( $M = .09$ ),  $t(47) = 25.48$ ,  $SEM = .026$ ,  $d = 4.48$ , demonstrating reliable true memory. There also were typical relatedness effects on false recognition: False recognition of strongly related lures (.57) was greater than that of weakly related lures (.28),  $t(47) = 8.99$ ,  $SEM = .032$ ,  $d = 1.14$ , and both types of false alarms were greater than false alarms to the corresponding unrelated control lures (.17 and .11, respectively, both  $ps < .01$ ,  $ds = 1.73$  and  $0.99$ ). Similar effects were apparent in the AD patients. Studied words were recognized more often than control lures (.61 and .30),  $t(47) = 9.57$ ,  $SEM = .033$ ,  $d = 1.19$ , and strongly related lures (.53) were falsely recognized more often than weakly related lures (.35),  $t(47) = 8.13$ ,  $SEM = .023$ ,  $d = .62$ . There was a relatedness effect (related > unrelated) on false recognition for strong lures (.53 and .38),  $t(47) = 4.94$ ,  $SEM = .031$ ,  $d = .48$ , and a similar (albeit nonsignificant) pattern was found for weak lures (.35 and .30),  $t(47) = 1.72$ ,  $p = .09$ ,  $d = .16$ .

Because of differences in false alarms to the different types of unrelated control lures (especially across groups), all subsequent analyses are reported on data that were adjusted by subtracting false alarms to unrelated control lures. Adjusted data for list words and related lures are graphed in Figure 1. Adjusted false recognition to weak lures was close to floor levels in AD patients in the mixed condition, so we excluded these items from the blocking analyses and only considered false recognition to strong lures. As in prior DRM studies, these strong lures were the critical nonstud-

ied associates of each list. A 2 (group: control subjects, AD patients)  $\times$  2 (item: studied words, strong lures)  $\times$  2 (blocking: blocked, mixed) analysis of variance (ANOVA) revealed a main effect of group,  $F(1, 92) = 72.26$ ,  $MSE = .06$ ,  $\eta_p^2 = .440$ , replicating AD-related impairments in both true memory and gist-based false memory (e.g., Budson, Sitarski, et al., 2002, Budson, Sullivan, et al., 2002). There also was a main effect of item type,  $F(1, 92) = 103.67$ ,  $MSE = .022$ ,  $\eta_p^2 = .530$ , indicating significant item-specific memory in each group (true recognition > false recognition), and a main effect of blocking,  $F(1, 92) = 19.66$ ,  $MSE = .06$ ,  $\eta_p^2 = .176$ , demonstrating the typical DRM blocking effect (blocked > mixed). Finally, there were three significant interactions (Item  $\times$  Group, Item  $\times$  Blocking, and Item  $\times$  Group  $\times$  Blocking).<sup>3</sup> To explore these interactions, and to address the primary questions outlined in the introduction, we conducted two different sets of follow-up ANOVAs: Group  $\times$  Blocking effects were analyzed separately for each item type, and Item  $\times$  Blocking effects were analyzed separately for each group.

### Associative Blocking Effects

We first conducted ANOVAs on each item type to compare the magnitude of the blocking effect across groups. The most critical comparison was for false recognition of strong lures. Here, there was a main effect of group, in which control participants > AD patients,  $F(1, 92) = 35.75$ ,  $MSE = .041$ ,  $\eta_p^2 = .280$ , a main effect of blocking (in which blocked > mixed),  $F(1, 92) = 26.45$ ,  $MSE = .041$ ,  $\eta_p^2 = .223$ , and an interaction that was significant with a one-tailed test,  $F(1, 92) = 2.94$ ,  $MSE = .041$ ,  $\eta_p^2 = .031$ .<sup>4</sup> The interaction indicates that blocking the lists increased false recognition more in control participants than in AD patients (see Figure 1), consistent with the idea that gist-based processing was impaired in AD patients. For studied words, there was a main effect of group, in which control participants > AD patients,  $F(1, 92) = 74.28$ ,  $MSE = .041$ ,  $\eta_p^2 = .447$ ; a main effect of blocking, in which blocked > mixed,  $F(1, 92) = 6.00$ ,  $MSE = .041$ ,  $\eta_p^2 = .061$ ; and no interaction ( $F < 1$ ). The lack of an interaction indicates that blocking had a similar effect on true recognition in both groups, but this pattern is difficult to interpret because of the different contributions of item-specific and gist memory to true recognition (discussed next).

The blocking effects on false recognition suggest that AD patients had impaired gist memory, but a separate question concerns whether AD patients were less likely than controls to strategically rely on gist when making their decisions. To explore this issue, and to further investigate the interactions discussed previously, we conducted ANOVAs comparing blocking effects on true and false recognition within each group. For control participants, there was a main effect of blocking,  $F(1, 46) = 15.29$ ,  $MSE = .052$ ,  $\eta_p^2 = .249$ , a main effect of item type,  $F(1, 46) = 78.46$ ,  $MSE = .022$ ,  $\eta_p^2 = .630$ , and a significant interaction,  $F(1, 46) = 11.37$ ,  $MSE =$

Table 2  
Mean Proportion of Words Recognized as a Function of Study Condition

Item	Controls		Patients	
	Mixed	Blocked	Mixed	Blocked
List words	.75 (.04)	.78 (.03)	.54 (.06)	.69 (.04)
List word controls	.12 (.03)	.07 (.02)	.28 (.06)	.32 (.05)
Strong lures (SLs)	.45 (.05)	.68 (.06)	.44 (.07)	.63 (.06)
Strong lure controls	.20 (.04)	.14 (.03)	.36 (.07)	.41 (.06)
Weak lures	.25 (.04)	.30 (.04)	.32 (.06)	.37 (.05)
Weak lure controls	.13 (.03)	.10 (.02)	.28 (.06)	.33 (.05)

Note. Standard errors of each mean are in parentheses. Proportions for list words and list word controls were based on 24 items per participant; all other proportions were based on 12 items per participant.

<sup>3</sup> As an alternative to subtraction, we also computed  $d'$  statistics for both studied words and strong lures (using the entire data set). The  $d'$  data yielded the same pattern of statistical results and conclusions as simple subtraction, except that the Item  $\times$  Group  $\times$  Blocking interaction was not significant.

<sup>4</sup> When  $d'$  scores were analyzed, this interaction was significant with a two-tailed test,  $F(1, 92) = 4.37$ ,  $MSE = .584$ ,  $\eta_p^2 = .045$ .



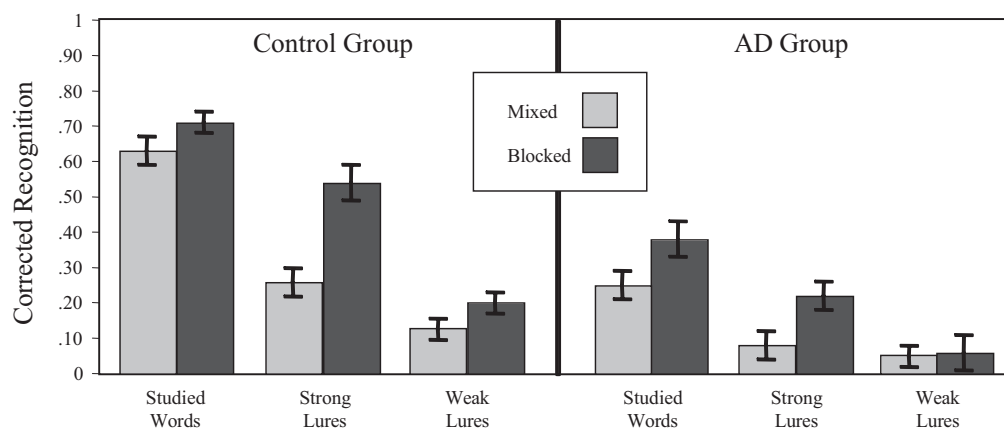


Figure 1. Adjusted recognition (related minus unrelated) for studied words and strong lures in controls (left panel) and patients with Alzheimer's disease (AD) (right panel). Bars represent standard errors of the mean.

.022,  $\eta_p^2 = .198$ . The interaction replicates previous findings in younger adults (e.g., Toglietta et al., 1999), and extends this pattern to a group of healthy older adults. Ostensibly, control participants were able to use item-specific recollections to recognize studied words; consequently, these items were affected less by the gist manipulation (blocking) than were related lures. A different pattern emerged for AD patients. There was a main effect of item type,  $F(1, 46) = 30.28$ ,  $MSE = .021$ ,  $\eta_p^2 = .397$ , and a main effect of blocking,  $F(1, 46) = 6.11$ ,  $MSE = 0.68$ ,  $\eta_p^2 = .117$ , but no interaction ( $F < 1$ ). Unlike the control participants, true and false recognition were equally affected by blocking in the AD patients, suggesting that these participants were influenced by gist even when responding to studied words.

#### Associative Strength Effects

We also analyzed the effects of associative strength on false recognition. As discussed, we found the predicted effect of associative strength on false recognition (strong lures > weak lures) in each group, but the critical question was whether these effects were reduced in AD patients relative to controls. A 2 (lure type)  $\times$  2 (group) ANOVA, collapsed across the blocking conditions, revealed a main effect of lure type,  $F(1, 94) = 50.86$ ,  $MSE = .028$ ,  $\eta_p^2 = .351$ , a main effect of group,  $F(1, 94) = 32.16$ ,  $MSE = .051$ ,  $\eta_p^2 = .255$ , and a significant interaction,  $F(1, 94) = 6.98$ ,  $MSE = .028$ ,  $\eta_p^2 = .069$ . The interaction confirms that associative strength had a larger effect in control participants than in AD patients.

As an additional test, we analyzed the associative strength of each of the 24 strong lures. We first calculated the probability of falsely recognizing each strong lure, across participants, and then subtracted the probability of falsely recognizing this same lure when the corresponding list was not studied (i.e., control lures). This was done separately for controls and AD patients, collapsing across blocking conditions to increase the number of observations for each item ( $n = 48$  participants). We then correlated false recognition with associative strength, across the 24 strong lures. We found a positive correlation for control participants,  $r(24) = .39$ ,  $p < .05$ , one-tailed, replicating the expected effect of associative strength on false recognition (e.g., Roediger et al., 2001).

The analogous correlation for AD patients was not significant,  $r(24) = .08$ , even though the variability in false recognition scores was just as large in AD patients ( $M = .15$ ,  $SD = .19$ ) as in control subjects ( $M = .40$ ,  $SD = .16$ ). This analysis provides further evidence that AD impaired the influence of associations on false recognition (e.g., memory for the associative themes or gist of each list), as opposed to more strategic uses of gist in memory decisions.

#### Neuropsychological Tests

To gain insight into the patient's gist memory impairments, we analyzed their performance on the neuropsychological tests. We used verbal fluency to animals as a measure of semantic memory and the Memory subtest from the Alzheimer's Disease Assessment Scale (ADAS) as a measure of episodic memory for unrelated words (for the latter test, higher scores indicate worse performance). We correlated each of these standardized measures with gist-based false recognition (i.e., adjusted false alarms to strong lures). To increase our power and to reduce the number of comparisons, we collapsed across the blocking conditions (43 patients had data for both tests). Both verbal fluency ( $r = .42$ ,  $p < .01$ ) and ADAS Memory ( $r = -.30$ ,  $p < .05$ ) were significantly correlated with false recognition, and the former relationship remained significant even after controlling for overall levels of dementia (via Mini-Mental State Examination scores) in a partial correlation ( $r = .38$ ,  $p = .01$ , and  $r = -.29$ ,  $p = .07$ , respectively). Although they are only suggestive, these correlations are consistent with the idea that dysfunction of both semantic and episodic memory contribute to the patients' impaired gist memory for associative word lists.

In addition to impairments in gist memory, the present results provide strong evidence that AD patients were impaired in item-specific recollections. As in previous studies conducted with the DRM task (e.g., Balota et al., 1999; Budson, Sitarski, et al., 2002; Budson, Sullivan, et al. 2002), we found lower levels of adjusted true recognition in AD patients than in control participants. However, all of these previous comparisons were confounded by the influence of gist memory on true recognition (with gist memory being lower in AD patients). A stronger comparison can be made

in the current study, because controls in the mixed condition and AD patients in the blocked condition were equated on gist-based false recognition of strong lures (.26 and .22, respectively),  $t(46) < 1$ . Even though these two groups had similar levels of gist memory by this measure (see Figure 1), large differences in true recognition were still obtained (.63 and .38),  $t(46) = 4.11$ ,  $SEM = .062$ ,  $d = 1.17$ . AD patients did demonstrate item-specific memory, as reflected in their ability to discriminate studied words from related lures, but this type of recollection clearly was impaired relative to control participants.

### General Discussion

Previous studies indicate that, in its early stages, AD reduces the influence of gist on false recognition (e.g., Budson, Sitarski, et al., 2002; Budson, Sullivan, et al., 2002). The cause of this effect has been unclear. One possibility is that AD impairs gist memory, potentially as a result of difficulties extracting and encoding gist information, whereas another possibility is that AD patients are less likely to strategically rely on gist information in memory decisions. In the current study, we found that the effects of associative blocking and associative strength on false recognition were smaller in AD patients compared with controls. Assuming that the effects of blocking and strength are driven by the relatively automatic influences of gist and associations in memory, these results support the idea that AD impairs memory for gist information, per se, and does not simply reduce the likelihood of strategically using gist information at test. In fact, blocking affected true and false recognition equally in AD patients, but not in control subjects, suggesting that AD patients were more likely than controls to rely on gist at test.

The other main result from our experiment was that true recognition was impaired in AD patients, relative to controls, even when the two groups were matched on gist-based false recognition of strongly related lures (via the blocking manipulation). This pattern suggests that item-specific recollections were more impaired than gist memory in AD patients. Deficits in item-specific memory might explain why blocking influenced true and false recognition equally in AD patients but not in control participants. If item-specific recollections were degraded more than gist memory in AD patients, then they would have been influenced more by gist information (relative to item-specific information) when responding to studied words. Thus, even though gist memory was impaired in AD patients, they were more reliant on this information when making recognition decisions than were control participants.

The idea that item-specific recollections are impaired more than gist memory in AD is consistent with fuzzy trace theory (e.g., Brainerd & Reyna, 2005), which predicts that gist traces are more resistant to forgetting than item-specific (or verbatim) traces. The current findings also can be explained by theories of DRM false recognition that do not assume that an independent gist trace is extracted and separately stored for each list. Feature-based models predict that false recognition of related lures can be more resistant to forgetting than true recognition of studied words (e.g., Arndt & Hirshman, 1998; Hintzman, 1986), and so can purely associative models of memory that assume greater associative activation of related lures (at study or test) relative to studied words (e.g., McEvoy, Nelson, & Komatsu, 1999). Our experiment was not designed to distinguish between these different theories of false

recognition, and they are equally effective at explaining the present results (and most other results in the DRM task).

Although we have treated gist and associative information interchangeably in the current study, it is possible to separate these factors, drawing on other materials. A recent study by Budson, Todman, and Schacter (2006) provided evidence that AD patients have gist memory deficits that generalize beyond semantic associations. Participants studied several lists, each containing different pictures of the same common object (the objects were presented in a mixed order at study). Because these lists contained multiple items with the same meaning, they did not require the same amount of semantic or associative processing as DRM lists (which contain multiple items with different meanings). Nevertheless, Budson et al. found that AD patients had impaired memory for the gist of the lists relative to control participants. There is also evidence that AD patients are influenced less by gist even when abstract materials that contain no semantic information are used (Budson et al., 2001). Difficulties processing semantic or associative information in AD might influence the DRM task, but the results from these other tasks indicate that other factors are likely involved, such as episodic memory deficits (i.e., difficulties encoding and/or retrieving gist information, in general). The finding that both verbal fluency and episodic memory predicted gist-based false recognition in the current study further suggests that both semantic and episodic deficits can contribute to gist memory deficits in AD.

The idea that impaired episodic memory contributes to the gist memory deficit in AD also gains support from studies of patients with medial temporal amnesia. Like AD patients, these amnesic patients have impaired episodic memory, but unlike AD patients, the processing of semantic information can be relatively spared. Using a gist-test similar to Budson et al. (2006), with DRM word lists as study materials, Verfaellie et al. (2002) found impaired gist memory in patients with medial temporal amnesia. These results suggest that episodic memory impairments are sufficient to cause a deficit in gist memory, in the absence of semantic memory impairments. It is important to note, however, that there were some behavioral differences between the two patient groups in the two studies: Whereas AD patients showed reduced gist memory only after false recognition data were adjusted for responses to unrelated lures (as in the present study), patients with medial temporal amnesia showed reduced gist memory on both raw and adjusted data. The reason for these differences is unclear, but further investigation of the gist memory deficits across these groups seems warranted.

In conclusion, our results raise an important question about the relative weighting of gist memory and item-specific recollections at the time of retrieval. Our working hypothesis is that impairments in item-specific recollections caused AD patients to rely more on gist memory than control subjects when making their recognition decisions. However, it is unclear whether this shift was obligatory (i.e., impaired item-specific recollections left AD patients more susceptible to the automatic influences of gist) or whether it was under conscious control (i.e., because item-specific recollections were impaired, AD patients decided to rely more on gist-based information to make decisions). The degree to which the influence of these two types of information (gist and item-specific) can be consciously controlled, and whether this control changes over the

progression of the disease, will be important research directions for understanding memory distortion in Alzheimer's patients.

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Received September 19, 2005

Revision received May 22, 2006

Accepted May 24, 2006 ■

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