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Discrimination and Reliance on Conceptual Fluency Cues are Inversely Related in Patients with Mild Alzheimer's Disease

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Abstract

Prior work suggests that patients with mild Alzheimer's disease (AD) often base their recognition memory decisions on familiarity. It has been argued that conceptual fluency may play an important role in the feeling of familiarity. In the present study we measured the effect of conceptual fluency manipulations on recognition judgments of patients with mild AD and older adult controls. "Easy" and "hard" test conditions were created by manipulating encoding depth and list length to yield high and low discrimination, respectively. When the two participant groups performed identical procedures, AD patients displayed lower discrimination and greater reliance on fluency cues than controls. However, when the discrimination of older adult controls was decreased to the level of AD patients by use of a shallow encoding task, we found that controls reliance on fluency did not statistically differ from AD patients. Furthermore, we found that increasing discrimination using shorter study lists resulted in AD patients decreasing their reliance on fluency cues to a similar extent as controls. These findings support the notion that patients with AD are able to attribute conceptual fluency to prior experience. In addition these findings suggest that discrimination and reliance on fluency cues may be inversely related in both AD patients and older adult controls.

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Keywords

recognition memory; Alzheimer's disease; fluency; recollection; familiarity; dual process; false memory

Introduction

Recollection and familiarity represent two distinct processes thought to underlie recognition memory decisions (Kelly & Jacoby, 2000; Mandler, 1980; Yonelinas, 2002). Recollection refers to the retrieval of specific context-bound information about an item or event, while familiarity is defined as a more general, acontextual sense that an item or event has been previously encountered. Findings from a variety of recognition memory paradigms indicate that both processes are impaired in patients with Alzheimer's disease (AD), with a greater decrement in recollection than familiarity reported by many [(A E Budson, Desikan, Daffner, & Schacter, 2000; Dalla Barba, 1997; Gallo, Sullivan, Daffner, Schacter, & Budson, 2004; Westerberg et al., 2006); although see (Wolk, Signoff, & Dekosky, 2008)]. Several of these studies report diminished veridical recognition and enhanced false recognition for AD patients compared to healthy age-matched controls, apparently due to reliance on familiarity in the absence or near-absence of recollection [e.g., (Budson et al., 2000)].

To better understand how AD patients make recognition memory decisions, it may be valuable to explore the underpinnings of familiarity. Jacoby and Whitehouse suggested that one important source of the subjective feeling of familiarity is the processing *fluency* of an item or event (Jacoby & Whitehouse, 1989). Fluency is defined as the relative ease of processing a stimulus, such that processing a highly fluent stimulus is less effortful than processing a less fluent stimulus. The notion that fluency may be a cue to prior presentation arises from the finding that items are easier to identify when represented, even if done so in a degraded fashion (Jacoby & Dallas, 1981). Therefore, when making recognition memory judgments participants could use enhanced processing fluency as a cue that an item was previously studied (Kelly & Jacoby, 2000). In support of this idea, manipulations that alter *perceptual fluency*, such as varying the visual clarity or size of test items, influence how subjects respond on tests of recognition memory. Items that are highly fluent are more likely to be endorsed as having been on a prior study list than are less fluent items, regardless of whether the items at test were studied or unstudied (Jacoby & Whitehouse, 1989; Whittlesea, Jacoby, & Girard, 1990).

Manipulations of the *conceptual fluency* of test stimuli also influence recognition memory judgments (Rajaram & Geraci, 2000; Whittlesea & Williams, 2000, 2001). In a paradigm developed by Whittlesea and colleagues, either conceptually predictive or non-predictive, but semantically consistent, sentence stems precede test words. True and false recognition rates are elevated by the presence of the conceptually predictive context compared to the non-predictive one. For example, participants are more likely to say that the word "boat" was on a study list if it follows the predictive context, "The stormy seas tossed the…" than the non-predictive context, "She saved up her money and bought a…" The predictive context is thought to enhance the ease of conceptual processing which in turn fosters a feeling of familiarity that is mistakenly attributed to prior study of the test item. Indeed, it may be that an "attributional" process—and not simply the fluency manipulation itself—leads to the conscious feeling of familiarity (Whittlesea & Williams, 2001; Wolk et al., 2004). That is, enhanced fluency may not result in an increased rate of endorsing items as previously studied unless the participant feels that this enhancement is related to prior study and not to an alternative source. For example, when young adult participants are consciously aware that fluency is being experimentally manipulated, it no longer impacts recognition judgments (Jacoby & Whitehouse, 1989; Whittlesea & Williams, 2001). Further, the strategy undertaken at the time

of retrieval may modulate whether or not fluency cues are utilized (Miller, Marianne, & Westerman, 2008; Willems, Salmon, & Van der Linden, 2008). For example, perceptual fluency manipulations are less likely to impact performance if study and test modality differ, presumably because perceptual fluency is felt not a reliable cue of prior study in this context (Willems et al., 2008).

As noted above, AD patients appear to rely on familiarity to a greater extent then age-matched controls when making recognition decisions. Since fluency manipulations have been shown to influence familiarity-based responding, it follows logically that fluency manipulations might have a marked effect on the recognition decisions of AD patients. Only a few of studies have evaluated the effects of fluency manipulations in memory-impaired populations. Verfaellie and Cermak found that patients with amnesia, mostly due to Korsakoff's syndrome, were more dependent than control subjects on manipulations of perceptual fluency in their recognition performance (Verfaellie & Cermak, 1999). Similarly, a study of AD patients reported a greater dependence on fluency than controls in a paradigm that manipulated the conceptual fluency of ambiguous drawings (Gold, Marchant, Koutstaal, Schacter, & Budson, 2007).

Additionally, Wolk et al. investigated the reliance of AD patients on conceptual fluency cues using the paradigm developed by Whittlesea and colleagues described above (Wolk et al., 2005). As with healthy subjects, it was expected that AD patients would demonstrate a greater likelihood to endorse items as previously studied following a predictive relative to non-predictive context (e.g., demonstrate the fluency effect). Moreover, given the poorer memory of these patients, it was hypothesized that this effect would actually be larger for the patients than the controls, consistent with prior work demonstrating a greater dependence on fluency cues in the setting of weaker memory (Verfaellie & Cermak, 1999; Westerman, Miller, & Lloyd, 2003; Wolk et al., 2005). While AD patients did demonstrate use of fluency cues in their recognition memory judgments, they did not do so to a greater extent than the older adult controls. The lack of a greater reliance on fluency in the AD patients was felt possibly related to the difficulty of the task, as discrimination was poor for both the healthy elderly controls and patients with AD. An alternative explanation was that impoverished semantic networks, a well-described finding in AD (Revonsuo, Portin, Juottonen, & Rinne, 1998; D. P. Salmon, Heindel, & Lange, 1999), may have reduced the impact of the experimental manipulation on fluency itself and have counter-acted any increased tendency to rely on such cues.

In the current study, we sought to expand upon the findings of Wolk et al (2005). For the central comparison of the current study, we used an encoding task that produced higher levels of discrimination than that reported in Wolk et al. to avoid the near floor performance of both controls and AD patients in that study. In this context, we predicted that AD patients would have poorer discrimination and, thus, rely on fluency cues to a greater extent than the older controls.

To further map the relationship between discrimination and reliance on fluency, additional manipulations were undertaken to modulate performance in both groups. In the first follow-up comparison, we sought to match the discrimination of older adult controls and AD patients by depressing the discrimination of the former. If reliance on fluency cues is purely driven by memory performance in both groups, we predicted that older adults and patients with AD would have similar effects of fluency when matched for discrimination. Additionally, our prior work had suggested that older controls can reduce their reliance on fluency in the setting of high discrimination (Wolk et al., 2005), similar to findings in younger participants. A limited range of performance in this study for AD patients prevented effective analysis of whether these patients are also able to "turn off" their reliance on fluency cues when memory is stronger. As the ability to modulate reliance on such cues has important implications for how AD patients

handle different memory contexts, we sought to directly address this issue with an additional manipulation producing higher discrimination in the patients with AD.

Finally, as noted above, additional factors outside of memory performance appear to modulate reliance on fluency cues, including the degree to which the experimental manipulation itself enhances fluency relative to the subject's expectations (Whittlesea & Williams, 2001). To investigate how Alzheimer's disease may alter this relationship, sentence stems were divided into high, moderate, and low predictability categories. Prior work has suggested that in the context of highly predictive sentence stems, fluency may be "attributed" to the manipulation itself rather than to prior study (Whittlesea & Williams, 2001). In other words, the experimentally derived fluency is an "expected" outcome of the manipulation rather than thought due to prior study. Our previous work has suggested that this attributional process may be dependent on frontal lobe function and such activity may serve to inhibit a more automatic tendency to assume that the enhanced fluency is due to prior study (Wolk et al., 2004, 2005). While we predicted that the controls might display a decreased reliance on fluency cues in the highly predictive relative to moderate/low predictive conditions for the reasons noted above, we hypothesized that patients with AD would demonstrate the opposite pattern due to two potential reasons. One is that even mild AD is associated with frontal lobe pathology, which could impact this attributional process in the setting of high expected fluency (Amieva, Phillips, Della Sala, & Henry, 2004; Baddeley, Baddeley, Bucks, & Wilcock, 2001; Perry, Watson, & Hodges, 2000). Second, low predictive stems may less effectively produce enhanced fluency in the AD group due to the impoverished semantic networks associated with AD.

Methods

Participants

Twenty-nine older adult controls (12 male) and 27 patients (13 male) with a clinical diagnosis of probable AD, as determined by the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association criteria (McKhann, Drachman, Folstein, Katzman, & Price, 1984), were recruited for the experiment. Many of the older adult controls were recruited from community listings in the greater Boston area. The remaining healthy elderly participants were spouses and friends, but not blood relatives, of the AD patients who participated in the present study. The participants with AD were recruited from the clinical populations of the Memory Disorders Unit, Brigham and Women's Hospital, Boston, Massachusetts, and the Alzheimer's Disease Research Center, University of Pittsburgh, Pittsburgh, Pennsylvania. The Internal Review Boards of Brigham and Women's Hospital and the University of Pittsburgh approved this study. Written informed consents were obtained from all participants.

The average age of older adult controls was 74.2 years (*SD* = 6.03); they reported an average of 16.5 years (*SD* = 3.10) of education. Older adult controls scored an average of 29.4 (*SD* = 0.90) on the Mini-Mental Status Exam (MMSE; (Folstein, Folstein, & McHugh, 1975). AD participants were 77.9 years old (SD = 8.9) and reported an average of 15.8 years (*SD* = 3.03) of education. AD participants scored an average of 24.7 (*SD* = 3.05) on the MMSE. Further demographic and psychometric data can be seen in Table 1.

Mean age of AD patients was about three years greater than the older adult controls, but this difference did not reach statistical significance, $F(1, 54) = 3.44$, $p = .069$. There was no significant difference in years of education between the controls and AD participants. As expected, older adult controls scored significantly higher on the MMSE than participants with AD, $F(1, 54) = 63.32$, $p < .001$. Older adult controls also scored significantly higher than AD participants on lexical fluency (D. P. Salmon & Butters, 1992), $F(1, 54) = 25.61$, $p < .001$, category fluency (D. P. Salmon & Butters, 1992), $F(1, 54) = 79.62$, $p < .001$, and immediate

recall, $F(1, 53) = 73.95$, $p < .001$, delayed recall, $F(1, 53) = 113.0$, $p < .001$, and recognition memory, $F(1, 53) = 69.17$, $p < .001$ on the CERAD word-list memory test (Morris et al., 1989). CERAD scores were not obtained for one older adult control participant. Each participant completed one of the encoding conditions. Within groups, older adult controls and AD participants were matched for age and years of education between encoding conditions ("Deep 90" and "Shallow" for older adult controls; "Deep 90" and "Deep 10" for AD participants).

Stimuli

One hundred and eighty one-syllable words were each matched with two sentence stems. Many of the sentence stem-word pairings were adapted from other studies (Hamberger, Friedman, & Rosen, 1996; Whittlesea & Williams, 2001). For each word, one sentence stem predicted the final word while the other was merely consistent with it (e.g. it made grammatical and semantic sense, but the final word would be unlikely to have been predicted based on the sentence stem). For example, for the word "NOSE", the predictive sentence stem was "He got a tissue and blew his…" while the non-predictive, but consistent, stem was "He drew a picture of a…" Each participant studied 90 words. At test, 180 sentence stems (90 predictive; 90 non-predictive) followed by corresponding test words (90 studied; 90 unstudied) were presented.

To establish the level of predictability (i.e. CLOZE probability) of the sentence stems, 20 Harvard University undergraduate students were presented with each of the stems and asked to generate a final word for the sentence. If a sentence stem led to generation of a particular word by 85% to 100% percent of the undergraduates, then the stem was considered highly predictive (high CLOZE probability) of that word. If a sentence stem led to generation of a word in 55% to 75% of respondents, then it was deemed moderately predictive (moderate CLOZE probability). Sentence stems that led to generation of a particular word in 35% to 45% of cases were termed low CLOZE probability for that word.

Procedure

The study session was self-paced. The words were visually presented individually in large uppercase font. In the "Deep 90" encoding condition, older adult controls and AD patients made verbal pleasantness judgments on 90 words in a single block. In the "Deep 10" encoding condition, AD participants made verbal pleasantness judgments on 10 words per study session, with nine total study-test blocks. In the "Shallow" encoding condition, older adult controls counted aloud the number of e's of each of 90 words in a single block. After each verbal response by the participant in all encoding conditions, the experimenter advanced to the next study word.

At test, sentence stems paired with studied and unstudied words were presented visually and auditorally. Auditory presentations ensured that participants at least heard each sentence stem if limited by slow reading. For studied and unstudied words each, 45 were preceded by predictive sentence stems (15 high, 15 medium, and 15 low CLOZE probability) and 45 by non-predictive sentence stems. The number of study and test items, as well as balance of predictive and non-predictive stems, was identical in all conditions. The "Deep 10" condition was broken into nine study-test blocks. In each of the nine test blocks, 10 studied (from the immediately preceding study list) and 10 unstudied words were presented (half of each with predictive and non-predictive sentence stems). Within each task, complete counterbalancing of items across the predictive/non-predictive and studied/unstudied conditions would require that the total number of subjects be a multiple of four, so complete counterbalancing was not achieved.

The testing protocols were very similar to those described in Wolk et al. (2005; see Figure 1). Sentence stem presentation time varied depending on duration of the auditory presentation. After the offset of the sentence stem, the following sequence occurred: a pause (250 ms), the sentence final word (1000 ms), a pause (500 ms), and finally an "Old or New?" prompt. Participants were told that "Old" responses indicated that they thought the word was on the previous study list while "New" responses indicated that they did not. Participants were instructed to refrain from responding until the "Old or New?" prompt appeared. The experimenter recorded each verbal response by the participant. After doing so, a plus ("+") sign appeared for 1000 ms to mark the start of the next block.

Results

Older Adult Controls vs. AD Patients in Deep 90 encoding condition

We first compared true and false recognition of older adult controls and AD patients in the Deep 90 encoding condition. True and false recognition data are presented in Table 2. A Group (older adult controls vs. AD patients) × Stem Type (high CLOZE, moderate CLOZE, low CLOZE, non-predictive) × Item Type (studied vs. unstudied) repeated measures ANOVA revealed effects of Group, $F(1, 26) = 6.51$, $MSE = .176$, $p = .017$, $\eta^2 = .200$, Stem Type, $F(3, 78) = 5.224$, $MSE = .012$, $p = .002$, $\eta^2 = .167$, and Item Type, $F(1, 26) = 225.9$, $MSE = .035$, $p < .000001$, $\eta^2 = .897$, and interactions of Group × Stem Type, $F(3, 78) = 4.97$, $MSE = .012$, $p = .003$, $\eta^2 = .160$, and Group × Item Type, $F(1, 26) = 102.0$, $MSE = .035$, $p < .000001$, $\eta^2 = .797$. There were no significant interactions of Stem Type × Item Type or Group × Stem Type × Item Type, Fs$(3, 78) < 1$. The effect of Group is present because overall the AD patients made more "old" responses to test items than older adult controls. The effect of Stem Type is present because the proportion of "old" responses was greater for words following predictive sentence stems than for words following non-predictive stems (removing non-predictive stems from the ANOVA also removed the effect of Stem Type, $F(2, 52) < 1$). The effect of Item Type exists because hit rates exceeded false alarm rates. Additional analyses were needed to explain the significant interactions.

To further investigate the Group × Stem Type interaction, we performed separate analyses for each group. For the older adult controls a Stem Type (high CLOZE, moderate CLOZE, low CLOZE, non-predictive) × Item Type (studied vs. unstudied) repeated measures ANOVA revealed an effect of Item Type, $F(1, 15) = 311.2$, $MSE = .041$, $p < .000001$, $\eta^2 = .954$, but no significant effect of Stem Type, $F(3, 45) < 1$ (i.e. no effect of fluency) or its interaction, $F(3, 45) < 1$. The effect of Item Type is present because the proportion of hits was greater than the proportion of false alarms.

For the AD patients the Stem Type × Item Type repeated measures ANOVA revealed significant effects of Item Type, $F(1, 11) = 14.2$, $MSE = .026$, $p = .003$, $\eta^2 = .563$, and of Stem Type, $F(3, 33) = 6.28$, $MSE = .017$, $p = .002$, $\eta^2 = .364$, but no Stem Type × Item Type interaction, $F(3, 33) < 1$. The effect of Item Type exists because the hit rate was greater than the false alarm rate. Examination of the data suggested that the effect of Stem Type was due to a lower proportion of "old" responses to words that followed non-predictive sentence stems compared to words that followed the three predictive stem types. To test this hypothesis we performed the same ANOVA as above, but with the non-predictive stem type removed. Removal of the non-predictive stem type from the analysis also removed the effect of Stem Type, $F(2, 22) < 1$. Thus, for predictive sentence stems there was no evidence that the degree of predictability (high, medium, or low CLOZE) influenced performance.

We calculated d' as a measure of discrimination (Figure 2). High values of d' indicate greater discrimination. A d' value of zero indicates chance performance. Because d' is undefined when the proportion of responses equals zero or one, all responses were converted using the formulas

previously described (Snodgrass & Corwin, 1988). To compare discrimination, we performed a Group (older adult controls vs. AD patients) × Stem Type (high CLOZE, moderate CLOZE, low CLOZE, non-predictive) repeated measures ANOVA with *d′* as the dependent variable. This ANOVA revealed an effect of Group, $F(1, 26) = 81.2$, $MSE = .836$, $p < .000001$, $\eta^2 = .757$, no effect of Stem Type, $F(3, 78) < 1$, and no interaction of Group × Stem Type, $F(3, 78) < 1$. The effect of Group is present because overall discrimination was greater for older adult controls than for AD patients.

We further calculated the "fluency effect" (Figure 3) as the proportion of "old" response to words preceded by non-predictive sentence stems subtracted from the proportion of "old" response to words preceded by predictive sentence stems (i.e, the average of the high CLOZE, moderate CLOZE, and low CLOZE conditions). We collapsed these three CLOZE conditions because the preceding analyses did not find differences between them for either the older adults or AD patients. Fluency values were calculated separately for studied and unstudied items. We performed a Group (older adult controls vs. AD patients) × Item Type (studied vs. unstudied) repeated measures ANOVA with the fluency effect as the dependent variable. This ANOVA revealed an effect of Group, $F(1, 26) = 7.90$, $MSE = .027$, $p = .009$, $\eta^2 = .233$, no effect of Item Type, $F(1, 26) < 1$, and no interaction of Group × Item Type, $F(1, 26) = 1.172$, $MSE = .008$, $p = .289$, $\eta^2 = .043$. The effect of Group is present because fluency values were greater for AD patients than for older adult controls, consistent with our prediction.

Effect of Decreased Discrimination in Older Adult Controls

In an attempt to match discrimination between the groups, we next compared the performances of older adult controls in the Shallow encoding condition to AD patients in the Deep 90 encoding condition (see Table 2). A Group (older adult controls vs. AD patients) × Stem Type (high CLOZE, moderate CLOZE, low CLOZE, non-predictive) × Item Type (studied vs. unstudied) repeated measures ANOVA revealed effects of Group, $F(1, 23) = 11.2$, $MSE = .318$, $p = .003$, $\eta^2 = .328$, Stem Type, $F(3, 69) = 8.11$, $MSE = .015$, $p = .0001$, $\eta^2 = .261$, and Item Type, $F(1, 23) = 21.2$, $MSE = .034$, $p = .0001$, $\eta^2 = .480$, but no interactions of Group × Stem Type, $F(3, 69) < 1$, Group × Item Type, $F(1, 23) < 1$, Stem Type × Item Type, $F(3, 69) < 1$, or Group × Stem Type × Item Type, $F(3, 69) = 1.03$, $MSE = .007$, $p = .385$, $\eta^2 = .043$. The effect of Group is present because overall hit and false alarm rates were greater for AD patients than for older adult controls. The effect of Stem Type is present because the proportion of "old" responses was greater for words following predictive sentence stems than for words following non-predictive stems (removing non-predictive stems from the ANOVA also removed the effect of Stem Type, $F(2, 46) < 1$). The effect of Item Type exists because hit rates exceeded false alarm rates. The lack of a Group × Stem Type interaction suggests that both groups were similarly influenced in the memory decisions by the fluency manipulation.

The lack of a Group × Item Type interaction suggests that we were successful in matching memory performance between the two groups. To further compare memory accuracy, we performed a Group (older adult controls vs. AD patients) × Stem Type (high CLOZE, moderate CLOZE, low CLOZE, non-predictive) repeated measures ANOVA with *d′* as the dependent variable (see Figure 2). This ANOVA revealed no effect of Group, $F(1, 23) < 1$ or Stem Type, $F(3, 69) < 1$ and no interaction of Group × Stem Type, $F(3, 69) < 1$. Thus, our attempt to match the groups on discrimination was successful.

To further compare the fluency effect in the setting of equivalent discrimination, we performed a Group (older adult controls vs. AD patients) × Item Type (studied vs. unstudied) repeated measures ANOVA with the fluency effect as the dependent variable as above (see Figure 3). This ANOVA revealed no effects of Group or Item Type and no interaction of Group × Item Type, Fs$(1, 23) < 1$. While the magnitude of the effect was smaller in the controls, the lack of a statistically significant Group difference suggests that the effect of fluency on memory

decisions was similar when discrimination was matched between the groups. Further, in the setting of low discrimination (i.e., Shallow encoding condition) older adults are influenced by conceptual fluency while in the context of high discrimination (i.e., Deep 90 encoding condition), they are apparently able to "turn off" their reliance on fluency cues.

Effect of Increased Discrimination in AD Patients

Finally, we performed analyses to determine if in the context of increased discrimination AD patients were also able to reduce their reliance on fluency cues. To do so, we had an additional group of AD patients perform the Deep 10 version of the paradigm in which the shorter study-test blocks allowed for enhanced discrimination relative to the "Deep 90" condition (see Table 2 and Figure 2). As anticipated, discrimination was greater in the "Deep 10" than the "Deep 90" condition, $F(1, 25) = 37.3$, $MSE = .800$, $p < .000001$, $\eta^2 = .598$.

We then labeled the two encoding conditions for each group as "easy" or "difficult," with the easy condition defined as the condition that yielded higher discrimination. For older adult controls, Deep 90 was labeled as the easy condition and Shallow was deemed the difficult condition. For AD patients, Deep 10 was labeled the easy condition while Deep 90 served as the difficult condition. To determine whether the difference in discrimination between the easy and hard test conditions were comparable between the two groups, we performed a Group (older adult controls vs. AD patients) × Stem Type (high CLOZE, moderate CLOZE, low CLOZE, non-predictive) × Difficulty (easy vs. hard) repeated measures ANOVA with d' as the dependent variable. This ANOVA revealed no interaction, but a trend towards an interaction of Group × Difficulty, $F(1, 52) = 3.46$, $MSE = .916$, $p = .068$, $\eta^2 = .062$. While this interaction did not reach significance, the statistical trend suggests that the difference in discrimination between the two conditions may have been somewhat larger for the controls.

To measure modulation of reliance on fluency cues by memory performance, we performed a Group (older adult controls vs. AD patients) × Item Type (studied vs. unstudied) × Difficulty (easy vs. hard) repeated measures ANOVA with the fluency effect as the dependent variable. This ANOVA revealed an effect of Difficulty, $F(1, 52) = 7.20$, $MSE = .023$, $p = .010$, $\eta^2 = .122$, but no statistically significant effects of Group, $F(1, 52) = 2.66$, $MSE = .023$, $p = .109$, $\eta^2 = .049$, or Item Type, $F(1, 52) = 1.89$, $MSE = .008$, $p = .175$, $\eta^2 = .035$, and no interactions of Group × Item Type, $F(1, 52) < 1$, Group × Difficulty, $F(1, 52) < 1$, Item Type × Difficulty, $F(1, 52) = 2.71$, $MSE = .008$, $p = .105$, $\eta^2 = .050$, or Group × Item Type × Difficulty, $F(1, 52) < 1$. The effect of Difficulty is present because both groups displayed greater reliance on fluency when items had been studied with the difficult encoding task (i.e., in the context of low discrimination). Notably, the absence of the Group × Difficulty interaction indicates that memory performance modulated reliance on fluency to a similar extent in both groups. It is worth noting that while the Group effect did not reach statistical significance, there was a weak trend for such an effect due to the AD patients having a somewhat larger overall fluency effect across the conditions.

Discussion

In this study we investigated the impact of conceptual fluency on recognition memory decisions in AD patients and healthy elderly controls. A principle finding of the current work is that AD patients appear to rely on fluency to a greater extent than healthy controls when tested under the same conditions. In this setting, discrimination is, as expected, poorer in the patients with AD. However, when discrimination is equated between the two groups, this difference in reliance on fluency cues is diminished. Further, we demonstrated that AD patients are also able to modulate their reliance on fluency cues with respect to their overall memory performance. Indeed, the relationship between discrimination and the fluency effect was quite similar across the two populations.

The finding that AD patients have the ability to rely on conceptual fluency when making recognition decisions is consistent with previous studies of fluency effects in memory-impaired populations (Gold et al., 2007; Verfaellie & Cermak, 1999; Wolk et al., 2005). The current report extends these findings by demonstrating that this reliance on such cues is greater than that in control participants under equivalent study-test conditions. Since conceptual fluency is thought to impact recognition decisions by engendering a feeling of familiarity (Kelly & Jacoby, 2000; Rajaram & Geraci, 2000; Whittlesea & Williams, 2001), this finding is in accordance with studies that report that AD patients may rely on familiarity to a greater extent than controls for their recognition memory judgments (Budson et al., 2000; Dalla Barba, 1997; Gallo et al., 2004; Westerberg et al., 2006).

Beyond supporting the notion that AD patients are able to attribute enhanced fluency to prior experience, the present study evaluated the relationship of discrimination and fluency. Consistent with work in young subjects and our prior study with healthy elderly controls (Verfaellie & Cermak, 1999; Westerman et al., 2003; Wolk et al., 2005), memory performance appeared to play a critical role in our control participant's use of fluency cues. Indeed, when discrimination was reduced in the Shallow encoding manipulation, the controls demonstrated an increased reliance on fluency cues relative to the Deep 90 condition, in which fluency did not appear to influence responding. In this setting, discrimination did not differ from that of the AD patients in the Deep 90 condition and reliance on fluency was not statistically different. Importantly, the capacity to alter the degree to which fluency cues are used was not limited to the controls, as the AD patients were also able to reduce their reliance on such cues in the setting of increased discrimination (Deep 10 condition). Taken together, these findings suggest that discrimination and reliance on fluency cues are inversely related and that this relationship remains intact in mild AD.

The present work echoes findings reported by Verfaellie and Cermak (1999) in patients with tempero-limbic amnesia. They found that this group used perceptual fluency cues to a greater extent then age-matched controls, who in turn displayed greater memory accuracy. However, when the memory performance of the two groups was equated by use of a counterfeit study list in which there could be no discrimination between studied and unstudied items, both groups utilized perceptual fluency cues to a similar extent. This result suggests that although patients with impaired memory rely on fluency cues to a greater extent than those with normal memory, healthy subjects also will rely on these cues when their memory is weak.

The present findings can be placed in the context of dual-process models of recognition memory (Kelly & Jacoby, 2000; Mandler, 1980; Yonelinas, 2002). As noted above, AD patients are thought to rely on familiarity to a greater extent than recollection for their recognition memory decisions relative to controls when under similar testing conditions (Budson et al., 2000; Dalla Barba, 1997; Gallo et al., 2004; Westerberg et al., 2006). Given that fluency is thought to only influence memory decisions based on familiarity (Rajaram & Geraci, 2000), it stands to reason that under equivalent testing constraints, such as the Deep 90 condition, AD patients would rely on fluency cues to a greater extent than controls. The older adult's greater use of recollection blunts the impact of fluency on memory decisions. However, when older subjects perform memory tasks that are less likely to support recollection, such as under the shallow encoding condition of the present study, familiarity drives memory decisions to a greater extent resulting in an increased utilization of fluency cues.

Interestingly, in the setting of relatively high discrimination, reliance on fluency cues may be reduced in AD patients to a similar extent to that of older adult controls. Again, it is likely the case that in the setting of high discrimination that older adults are able to use recollection, which would suppress their use of weak familiarity cues, such as those produced by the experimentally induced fluency. Changes in encoding conditions which impact the relative

balance of recollection and familiarity at test (e.g. shallow versus deep encoding) may alter the retrieval orientation or strategies used at test for making memory decisions that might modulate use of the experimentally-derived conceptual fluency cues (Rugg, Herron, & Morcom, 2002). Prior work has suggested that such strategies may play an important role in the utilization of fluency cues in both young and memory-impaired populations (Miller et al., 2008; Verfaellie, Giovanello, & Keane, 2001; Willems et al., 2008).

It is likely that similar factors were involved in the AD patient's reduction in the fluency effect in the Deep 10 relative to Deep 90 condition. While recollection is impaired in mild AD, it does not appear to be completely absent (Dalla Barba, 1997; Rauchs et al., 2007). Further, under conditions which enhance recollection in healthy subjects, such as deeper encoding or multiple study repetitions, patients with mild cognitive impairment (often conceptualized as early AD) or mild AD have been reported to demonstrate some degree of increased associative/recollective memory (Ally, Gold, & Budson, 2008; Gallo et al., 2004; Wolk et al., 2008). Thus, as with healthy controls, it is possible that the decreased reliance on fluency cues for the AD patients in the Deep-10 condition is due to a shift in the balance of the relative contribution of recollection and familiarity to their recognition memory performance. However, as discussed in more detail below, even when matched for discrimination, AD patients may rely more on familiarity than controls, and this could account for a generally higher fluency effect.

It is worth pointing out that even if increased familiarity alone accounted for the increased discrimination of the AD patients in the Deep 10 versus Deep 90 conditions (i.e. that there was no increase in recollection), this enhanced familiarity could still plausibly contribute to the reduction in reliance on experimentally-induced fluency cues –although perhaps not as effectively as recollection – based on several potential mechanisms. First, in the setting of a stronger familiarity signal for studied items, there is a smaller pool of items associated with low familiarity, which limits the number of items by which the experimentally enhanced fluency can alter responding (note that this is also true if recollection is increased). For example, in the present study AD patients' discrimination (hits minus false alarms) of words following non-predictive stems was 12% and 50% for the Deep 90 and Deep 10 conditions, respectively. These percentages approximate the proportion of studied items associated with some degree of memory strength based on prior study. The fluency manipulation would not be expected to modulate responding for those items actually remembered, as they will be endorsed as "old" on that basis. If we then assume that the fluency manipulation increases the likelihood of responding "old" for any given item by 15% and apply this to the pool of studied items not associated with memory, we might expect a ~13% (15 × 88%) and 7.5% (15 × 50%) increased rate of "old" endorsements following predictive stems in the Deep 90 and Deep 10 condition, respectively.

Consistent with this logic, both groups displayed a numerically greater difference in the fluency effect for unstudied relative to studied items in their respective high compared to low discrimination conditions (see Figure 3). However, it is worth noting that unstudied items were associated with a larger fluency effect in the lower discrimination condition for both groups. As all unstudied items should be associated with low familiarity regardless of discrimination, this suggests that additional factors reduced the fluency effect in the high versus low discrimination conditions in both groups.

A second mechanism by which increased discrimination in the absence of recollection could modulate the fluency effect is dependent on the notion that most subjects have an overall tendency or bias to respond "old" to approximately half of the items, give or take. When subjects can only remember a very small proportion of the items, such as the Deep 90 condition, they are actively searching for the tiniest signal that suggests that an item has been studied. It

is in this "low memory" condition that effects of fluency will be most prominent. In distinction, when many more items are remembered, these weak cues become less compelling (Deep 10).

Third, but related to the above, it is also possible that the AD patients used an alternative processing strategy in the setting of strong versus weak memory, regardless of whether or not the increased memory was due purely to familiarity. For example, a recent study reported that perceived task difficulty can alter whether AD patients use a "holistic" versus "analytic" processing strategy, which has implications for the reliance on fluency cues (Willems et al., 2008). Further, expectation of what cues are relevant for a task modulate how fluency manipulations impact responding and may alter the attribution of these cues to prior study (Jacoby & Whitehouse, 1989; Miller et al., 2008; Whittlesea & Williams, 2001). It may be the case that in the setting of increased discrimination that weak conceptual fluency cues were felt less diagnostic of prior study and were no longer attributed to it. Consistent with this notion, other work has suggested that AD patients retain some ability to make these kinds of meta-cognitive judgments (Budson, Dodson, Daffner, & Schacter, 2005; Waring, Chong, Wolk, & Budson, 2008). In the current paradigm, one could imagine that a subtle shift in the threshold of familiarity required for an "Old" response in the context of enhanced study-induced familiarity may reduce the impact of fluency manipulations on responding, as this effect likely produces only weak familiarity cues. Whatever the driving factors (increased recollection and/or familiarity), the fact that AD patients could alter their reliance on fluency suggests that while they may generally be more dependent on fluency cues for making memory judgments, this strategy is more related to their overall poorer memory than an obligate approach to recognition memory.

A couple additional points are worth making. First, although not statistically significant, AD patients appeared to have a generally higher fluency effect than the controls (see Figure 3). Indeed, there was a trend towards a group effect ($p = .109$) in the analysis of fluency effect by difficulty (high vs. low discrimination) due to a somewhat higher fluency effect in both settings for the AD patients. In the high discrimination conditions (controls: Deep 90; AD patients: Deep 10), this difference may be related to a trend towards higher discrimination in the control group. The higher discrimination of the controls may have further discouraged their relying on fluency cues relative to the AD patients. However, in the low discrimination condition (controls: Shallow; AD patients: Deep 90) memory accuracy was well matched, yet the AD patients still were influenced by fluency cues to a greater extent than the controls (13% versus 8%). This difference in magnitude could be related to an overall greater reliance on familiarity in the AD patients even when discrimination is matched. If fluency plays an important role in the basis of the feeling of familiarity, prior study- and experimentally-derived fluency would be expected to play a more important role when familiarity is relied upon to a greater extent for making memory decisions. While alterations in the familiarity strength of studied items may also impact reliance on experimentally produced fluency cues, as described above, it is likely that recollection would have a larger modulatory effect on use of such cues. Further work could determine whether or not reliance on recollection and familiarity differ in AD patients and healthy elderly controls even in the setting of matched discrimination. Work in amnesic patients has suggested that despite methods to match performance, memory impaired patients may have a different relative contribution of recollection and familiarity than control participants (Giovanello and Verfaellie, 2001). It is also worth noting that in the low discrimination conditions, patients with AD tended to have a more liberal response bias while controls tended to be become more conservative. The conservative bias of the controls may reflect a more stringent criteria to endorse an item as "old" and a decreased tendency to utilize fluency cues in memory decisions. The opposite may be true for the AD patients. Further, prior work has suggested that a more liberal bias, in general, tends to increase the contribution of familiarity to recognition memory decisions relative to recollection (Yonelinas, 2002) and AD

patients tend to generally respond in a more liberal manner (Budson, Wolk, Chong, & Waring, 2006).

Finally, we had also predicted that differences in reliance on fluency between AD patients and older adult controls would vary based on the degree of to which sentence stems predict the final word (CLOZE level). This prediction was based upon prior work that indicated that individuals with intact memory do not attribute fluency to past study when predictive sentence stems produce a very high level of fluency, probably due to increased awareness of the experimental manipulation (Jacoby & Whitehouse, 1989; Whittlesea et al., 1990; Whittlesea & Williams, 2001a). For example, Whittleasea and Williams found that young subjects are less likely to endorse an item as old if the sentence stem "completely" predicts the final word test item (e.g. Row, row, row your…BOAT). We hypothesized that AD patients may be less likely to inhibit the attribution of these items to prior study due to mild frontal lobe impairment. However, our findings did not support this prediction. The fluency effect did not significantly differ among test words preceded by high, moderate, and low CLOZE probability stems within either participant group. One explanation for this finding is that while the high CLOZE items were very predictable of the final word, most were not "completely" predictable (i.e. they did not have a CLOZE of 100%). Another possibility is that older adult controls may not display this change in attribution that has been described in young patients, perhaps, due to subtle age-related frontal lobe pathology. Further work could examine this potential age-related difference. Finally, our use of undergraduates to determine CLOZE levels may have produced groupings that do not completely generalize to the older subjects and patients of this study, limiting comparison across the stem conditions.

In conclusion, the present study demonstrates three major findings. First, when making recognition decisions patients with AD rely on conceptual fluency to a greater extent than older adult controls in the context of their poorer discrimination. Second, decreased discrimination in older adult controls diminishes this difference. Third, AD patients can modulate their use of fluency cues to a similar extent as healthy controls depending on their overall memory performance.

The capacity of patients with mild AD to use fluency cues in recognition memory tasks and the relative dependence of these patients on familiarity-based processing suggest that conceptual fluency cues may be critical for these patients' everyday memory outside of the laboratory. Techniques to maximally utilize fluency cues may actually improve recognition accuracy, as suggested in patients with amnesia (Dorfman, Kihlstrom, Cork, & Misiaszek, 1995; Verfaellie et al., 2001). However, when fluency is not related to prior study (as due to the present experimental manipulation), use of such cues may actually contribute to false recognition without aiding discrimination. The capacity of AD patients to alter their use of fluency cues in recognition memory decisions suggests that patients may be able to adjust their use of such cues to situations in which they are most appropriate.

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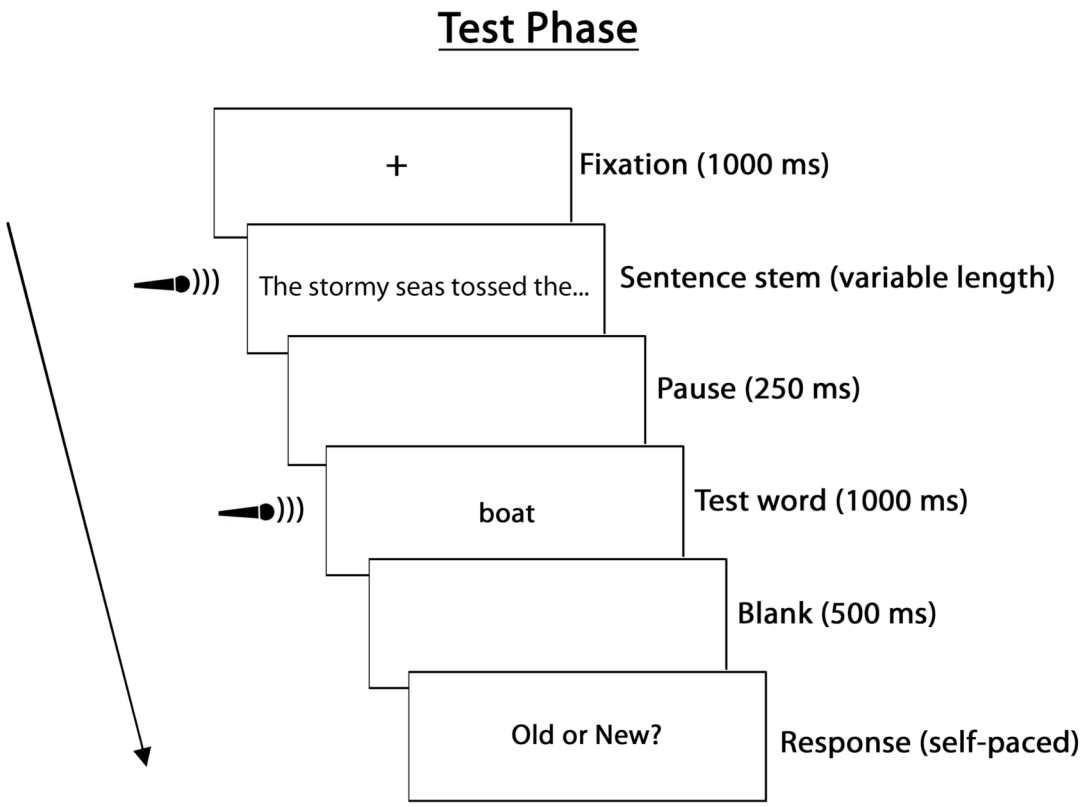

Figure 1.
Test phase procedure for all conditions.

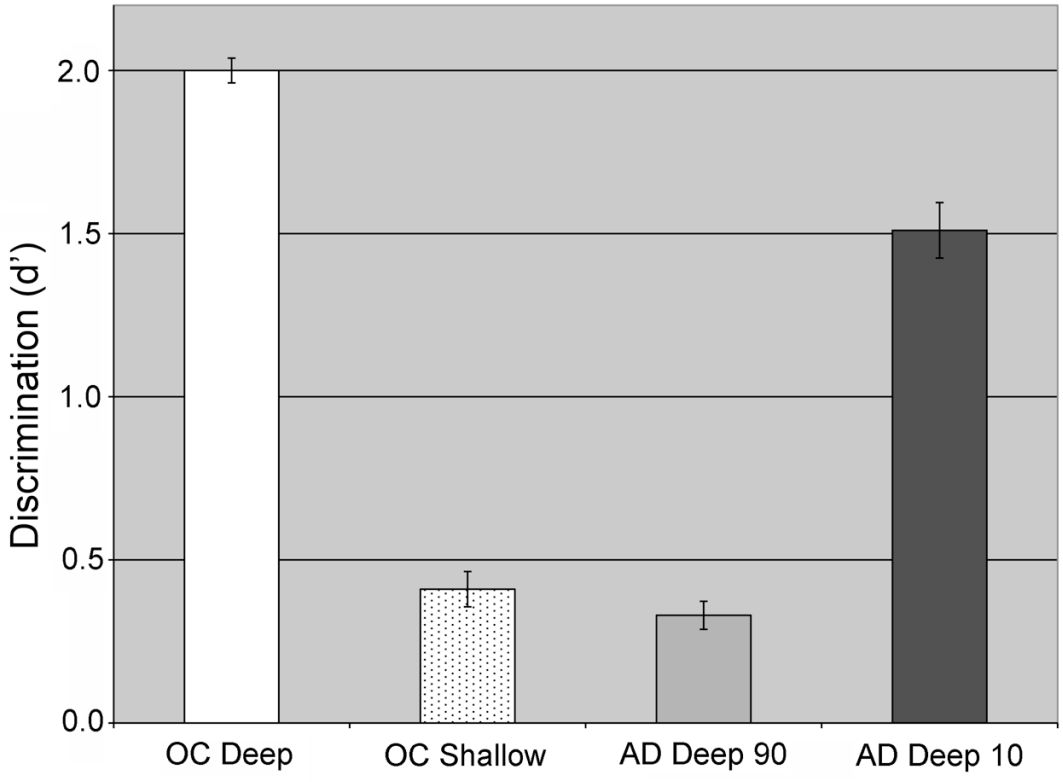

Figure 2.
Recognition discrimination (d′) presented by group and encoding condition. Error bars represent one standard error of the mean. Notes: OC = healthy older adults; AD = Alzheimer's disease; Deep 90, Shallow, and Deep 10 = the three encoding conditions.

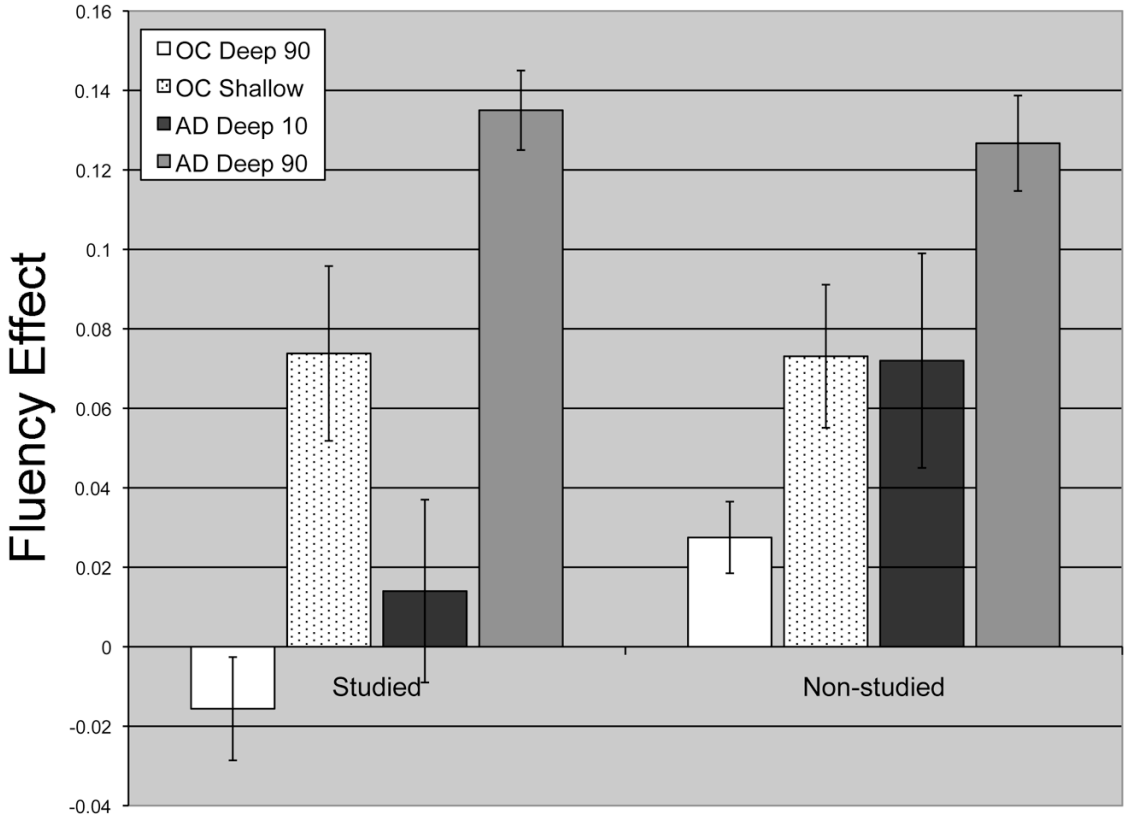

Figure 3.
Mean fluency effect values (proportion items endorsed "Old" following predictive stems minus non-predictive stems) for studied and unstudied items presented by group and encoding condition. Error bars represent one standard error of the mean. Notes: OC = healthy older adults; AD = Alzheimer's disease; Deep 90, Shallow, and Deep 10 = the three encoding conditions.

Table 1

Demographic and psychometric data for patients with Alzheimer's Disease and Controls. Standard deviations are listed in italics.

	OC (n=29)	OC Deep 90 (n=16)	OC Shallow 90 (n=13)	AD (n=27)	AD Deep 90 (n=12)	AD Deep 10 (n=15)
Age (yrs)	74.2 *(6.0)*	74.6 *(5.0)*	73.4 *(7.2)*	77.9 *(8.9)*	76.5 *(6.3)*	79.0 *(10.7)*
Education (yrs)	16.5 *(3.1)*	16.6 *(2.9)*	16.3 *(3.4)*	15.8 *(3.0)*	16.0 *(3.2)*	15.7 *(2.9)*
Gender	12 M; 17 F	7 M; 9 F	5 M; 8 F	13 M; 14 F	6 M; 6 F	7 M; 8 F
MMSE	29.4 *(0.9)*	29.5 *(0.7)*	29.2 *(1.1)*	24.7 *(3.1)*	24.8 *(2.4)*	24.8 *(2.4)*
Lexical Fluency	48.8 *(13.7)*	46.6 *(14.5)*	51.6 *(12.6)*	32.3 *(10.4)*	33.6 *(10.3)*	33.6 *(10.3)*
Category Fluency	47.7 *(11.1)*	44.9 *(9.1)*	51.1 *(12.7)*	25.8 *(6.6)*	23.3 *(5.4)*	23.3 *(5.4)*
CERAD						
Immediate	21.1 *(4.7)*	20.4 *(5.2)*	21.9 *(3.9)*	10.4 *(4.6)*	9.7 *(4.9)*	9.7 *(4.9)*
Delayed	6.9 *(2.2)*	6.9 *(2.4)*	6.9 *(2.1)*	1.2 *(1.7)*	1.3 *(1.4)*	1.3 *(1.4)*
Recognition	9.6 *(0.8)*	9.5 *(0.9)*	9.7 *(0.7)*	5.1 *(2.7)*	4.8 *(3.2)*	4.8 *(3.2)*

Note: OC = healthy older adults; AD = Alzheimer's Disease patients; MMSE = Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975); Lexical Fluency (F, A, and S; Salmon & Butters, 1992; Category Fluency (animals, vegetables, and fruits; Salmon & Butters, 1992). CERAD = Consortium to Establish a Registry for Alzheimer's Disease Word List Memory Test (Morris et al., 1989).

Table 2

Mean proportions of “old” responses to studied and unstudied items by group, encoding condition, and stem type

		Studied				Unstudied					
		High	**Mod**	**Low**	**NP**	**High**	**Mod**	**Low**	**NP**	**d′**	**C**
OC	Deep 90	.74 *(.17)*	.75 *(.15)*	.78 *(.14)*	.77 *(.15)*	.12 *(.09)*	.15 *(.14)*	.14 *(.13)*	.11 *(.09)*	2.00 (.62)	.25 (.30)
	Shallow	.41 *(.30)*	.39 *(.24)*	.40 *(.21)*	.33 *(.18)*	.26 *(.22)*	.32 *(.23)*	.27 *(.24)*	.21 *(.17)*	.41 (.39)	.63 (.62)
AD	Deep 90	.69 *(.24)*	.68 *(.25)*	.69 *(.24)*	.55 *(.22)*	.59 *(.20)*	.54 *(.27)*	.54 *(.24)*	.43 *(.20)*	.33 (.30)	−.15 (.55)
	Deep 10	.73 *(.23)*	.70 *(.24)*	.70 *(.23)*	.70 *(.21)*	.26 *(.23)*	.30 *(.21)*	.25 *(.15)*	.20 *(.13)*	1.51 (.68)	.09 (.63)

Note: “High,” “Mod,” and “Low” represent the different CLOZE probabilities of predictive stems. “NP” = non-predictive sentence stem. Discrimination (d′) and bias (C) were calculated according to standard formulas (Snodgrass & Corwin, 1988). Note that negative values of C represent a more liberal response bias. Standard deviations are listed in italics.