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# Conceptual Implicit Memory Performance in Alzheimer's Disease

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Alzheimer's disease (AD) patients often exhibit deficits on conceptual implicit memory tests such as category exemplar generation and word association. However, these tests rely on word production abilities, which are known to be disrupted by AD. The current study assessed conceptual implicit memory performance in AD patients and elderly control participants using a conceptual priming task that did not require word production (i.e., semantic decision). Memory performance was also examined using a category exemplar generation test (i.e., a conceptual priming task that required word production) and a recognition memory test. AD patients exhibited deficits on the semantic decision task, the category exemplar generation task, and the recognition memory task. The results indicate that the conceptual memory deficits observed in AD patients cannot be attributed completely to word production difficulties.

Individuals with Alzheimer's disease (AD) exhibit pronounced deficits in explicit tests of memory, such as free recall, cued-recall, and recognition (for reviews, see Nebes, 1992; Zec, 1993). In contrast, they often perform normally on perceptual implicit memory tests (for reviews, see Fleischman & Gabrieli, 1998; Maki, 1995). For perceptual implicit memory tests, participants are engaged in processing perceptual information at test (e.g., identifying words or pictures), and memory is measured either as a reduction in response time or as an increase in accuracy that is associated with items that have previously been presented. This facilitation in performance is referred to as priming (e.g., Graf & Schacter, 1985; for a review, see Schacter, Chiu, & Ochsner, 1993). AD patients have shown normal priming in the following perceptual implicit memory tasks: word pronunciation (e.g., Balota & Duchek, 1991; Ober, Shenaut, Jagust, & Stillman, 1991), lexical decision (e.g., Balota & Ferraro, 1996; Ober et al., 1991), perceptual identification (e.g., Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991; Keane, Gabrieli, Growdon, & Corkin, 1994), and stem completion (e.g., Deweer et al., 1994; Fleischman et al., 1997; Grosse, Wilson, & Fox, 1990; Partridge, Knight, & Feehan, 1990; however for conditions in which stem completion priming is disrupted, see Gabrieli et al., 1994; Heindel, Salmon, Shults, Walicke, & Butters, 1989; Keane et al., 1991; Shimamura, Salmon, Squire, & Butters, 1987).

In contrast to their generally normal performance on perceptual implicit memory tests, AD patients often exhibit pronounced priming deficits on conceptual implicit memory tests (for reviews, see Fleischman & Gabrieli, 1998; Maki, 1995; Meiran & Jelicic, 1995). For example, Salmon, Shimamura, Butters, and Smith (1988) used a free-association task in which participants were asked to generate associates to target words. They found that elderly control participants were more likely to produce items that were presented in an earlier study list but that AD patients failed to show such an effect. Similar conceptual priming deficits have been reported in other studies with this task (Brandt, Spencer, McSorley, & Folstein, 1988; Carlesimo, Fadda, Marfia, & Caltagirone, 1995; Huff, Mack, Mahlmann, & Greenberg, 1988; but see Vaidya, Gabrieli, Monti, Tinklenberg, & Yesavage, 1999). Conceptual priming deficits in AD patients have also been reported for the exemplar generation task in which participants are asked to produce examples of semantic categories, and priming on this task is measured as the likelihood of generating a studied compared with a nonstudied target item in response to the category cue (e.g., Monti et al., 1996; Vaidya et al., 1999; but see Maki & Knopman, 1996).

However, there are some conditions for which AD patients have exhibited normal levels of priming on conceptual implicit memory tests. For example, AD patients have shown equivalent conceptual priming effects relative to age-matched controls for strongly associated word pairs on the free-association task (Vaidya et al., 1999). In addition, Maki and Knopman (1996) found that AD patients and controls demonstrated equivalent category exemplar generation priming when they were required to generate words at study even though the AD patients showed less-than-normal priming when they simply repeated words at study. Normal conceptual priming in AD patients has also been observed using a sentence puzzle task (Reichard, Camp, & Strub, 1995). In this task, participants study a list of sentences and corresponding solutions; the sentence puzzles are difficult to understand without the corresponding solution (e.g., "The person was unhappy because the hole closed." Solution:

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"Pierced ears."). During the test phase, participants were faster to make decisions about whether the sentence–solution pairs made sense if the sentence–solution pairs were previously presented during the study phase. Participants were tested at 30-min and 1-week delays, and the AD group demonstrated equivalent priming effects to controls at both delays.

It is important to distinguish between "conceptual priming tasks" and "semantic priming tasks," as the effects of AD on these two types of memory tasks may be different (see Ober & Shenaut, 1995; Shenaut & Ober, 1996). Semantic priming tasks involve facilitation between two different, semantically related items that is measured over a very short interval. For example, on a semantic priming task the word *doctor* is identified more rapidly if it is immediately preceded by the word *nurse.* Results suggest that semantic priming remains intact in early AD (for a review, see Ober & Shenaut, 1995). We consider this type of priming further in the Discussion section.

One explanation for the effects of AD on conceptual implicit memory performance is that AD does not disrupt conceptual implicit memory processes directly but disrupts the word production processes that are required in many of these tests. This distinction is similar to the identification–production distinction proposed by Gabrieli et al. (1994), according to which AD patients show normal priming on tasks that require the identification of the target stimulus but impaired priming on tasks that require the production of a target stimulus.

Evidence that AD patients exhibit word production deficits includes findings that these patients exhibit severe deficits on verbal fluency tests (e.g., Ober, Dronkers, Koss, Delis, & Friedland, 1986) and naming tests (e.g., Appell, Kertesz, & Fisman, 1982; Cummings, Benson, Hill, Read, 1985). Moreover, as discussed earlier, they can exhibit deficits on priming tests that require word production such as the category exemplar generation (Monti et al., 1996; Vaidya et al., 1999) and free-association tasks (Brandt et al., 1988; Carlesimo et al., 1995; Huff et al., 1988; Salmon et al., 1988). Yet they perform normally on the sentence puzzle task, which does not require word production (Reichard et al., 1995). Furthermore, the finding that AD patients sometimes exhibit a deficit in the word stem completion test is also consistent with the hypothesis in that this perceptual implicit test requires word production. The finding that AD patients exhibit normal free-association priming when the items are high associates (Vaidya et al., 1999) is not easily accounted for by the identification–production hypothesis. However, using high associates may be sufficient to decrease the demands on word production processes to such an extent that significant deficits are no longer observed in AD patients. Thus, in general, the identification–production hypothesis appears to provide a reasonable account for much of the existing AD priming data.

In the current study, we tested the predictions of the identification–production hypothesis by examining conceptual implicit memory performance in AD patients using a priming task that does not require word production, the *semantic decision task* (Vriezen, Moscovitch, & Bellos, 1995). For this task, words and pictures are presented, and participants make speeded responses indicating whether the item is of a given type (e.g., "Is the object man-made?") or exhibits a certain quality (e.g., "Is the object larger than a breadbox?"). Vriezen et al. (1995) found that participants were faster to make decisions if the item was previously studied, even when the physical format changed from study to test (e.g., from word to picture) and, in some cases, when the semantic decision changed from study to test.

If AD patients show normal conceptual priming effects on the semantic decision test, then this finding would support the identification–production hypothesis. Such a pattern of results would indicate that AD does not result in a general deficit in conceptual implicit memory performance but rather that AD disrupts performance on tasks that involve word production processes. In contrast, if AD patients show a deficit in priming on the semantic decision task, then such a finding would suggest that the identification–production hypothesis does not accurately characterize the conceptual implicit memory performance of AD patients.

The current study also measured memory performance among AD patients and controls using a category exemplar generation task and a recognition memory test, to determine whether the AD patients were behaving in a manner consistent with AD patients examined in previous studies. On the basis of earlier studies we expected the AD patients to exhibit deficits on the exemplar generation test and on the recognition test.

## Method

### *Participants*

Twenty-one individuals with probable AD were recruited for participation. Each AD patient had been evaluated by a neurologist, neuropsychologist, and nurse practitioner at the University of California, Davis, Alzheimer's Disease Center and met the clinical criteria of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association for a diagnosis of probable AD (McKhann et al., 1984). Data from one AD patient was excluded from all analyses because over 20% of the patient's responses in the semantic decision test either took longer than 30 s or were made before the onset of the target item. The remaining 20 AD patients consisted of 12 female and 8 male AD participants ranging in age from 64 to 89 years ($M$ = 77.10, $SD$ = 6.66), and in education from 10 to 20 years ($M$ = 14.60, $SD$ = 2.91). The Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) scores for the patient group ranged from 15 to 26 ($M$ = 20.20, $SD$ = 3.11), suggesting that this group of patients was within the mildly to moderately impaired range (for a review, see Zec, 1993).

Twenty-one elderly normal control participants were recruited from the communities of Davis and Sacramento, California. They met all of the same exclusionary criteria as the AD patients (no history of alcohol abuse, vascular disease, depression, etc.). Control participants were required to obtain a minimum of score of 26 on the MMSE. Two controls were excluded from all analyses: one control participant obtained a score of 25 on the MMSE, and the other reported taking antidepressant medication. The remaining 19 controls consisted of 14 females and 5 males ranging in age from 66 to 89 years ($M$ = 75.16, $SD$ = 6.01), in education from 10 to 25 years ($M$ = 15.92, $SD$ = 3.14), and in MMSE score from 27 to 30 ($M = 29.11$, $SD = 0.94$). The AD and control groups did not differ in age, $t(37) = 0.96$, or education, $t(37) = -1.36$, but did differ in MMSE scores, $t(37) = -11.99$, $p < .001$. The AD patients and control participants were paid $10 per hour for participating.

## Materials

For the recognition memory test, 140 words were selected that ranged from 3–10 letters in length and had Kučera-Francis (1967) frequency values of 1 to 500 per million. One hundred twenty words were used as target items and 20 were used as buffer items for this task.

For the category exemplar generation task, four exemplars from each of six different man-made and six different naturally occurring categories (Battig & Montague, 1969) were used as target items (i.e., 48 target items in total). Eight additional items were chosen from among three additional man-made and three additional naturally occurring categories to be used as buffer items. Exemplars ranged from the 8th to 24th most frequently occurring exemplars for a given category. Target exemplars were divided into two study lists, each list containing 24 exemplars from 6 different categories. One list was assigned to serve as the study list and the other list was not studied. Study list assignment was counterbalanced across participants. Words were randomized within each study list such that no more than two items of the same type (man-made or natural) and no two exemplars from a given category occurred in succession. Four buffer items were added to each study list, two at the beginning and two at the end of each list. The 12 category names were used as test stimuli. No more than two categories of a given type (man-made or natural) occurred in succession.

For the semantic decision task, 120 pictures from Snodgrass and Vanderwart (1980) and their corresponding names were selected as target items. Half of the stimuli represented items that were bigger than a shoebox, and half were smaller than a shoebox. Note that the objective size of objects is somewhat ambiguous given that many objects can take on several different forms (e.g., the word *basket* represents an item that can be larger or smaller than a shoebox). Items were chosen for which agreement was reached by three independent raters (two of the authors, Andrew P. Yonelinas and Michele M. Lazzara, and a third rater). For each participant, 80 items were randomly selected to serve as study items, half of which were to be presented as pictures and half as words. The test list contained 120 items (i.e., 20 were pictures at study and test, 20 were words at study and test, 20 were pictures at study and words at test, 20 were words at study and pictures at test, 20 were pictures at test and were not studied, and 20 were words at test and were not studied). Additional items were selected from the Snodgrass and Vanderwart materials to serve as buffer items at the beginning of the study list (i.e., 15 items) and the test list (i.e., 5 items). Items were chosen such that there was no overlap between the items presented in the recognition memory test, the exemplar generation test, and the semantic decision task.

## Design and Procedure

Each participant was tested individually in two experimental sessions that each lasted 1 hr, and the sessions were scheduled to be at least 1 week apart. The first session included the recognition memory test followed by the category exemplar generation test, and the second session included the semantic decision task followed by the MMSE.

For the recognition memory task, the study words were presented one at a time in a randomized order on a computer screen. For half of the words (i.e., 40 items), participants were asked to make *yes–no* decisions indicating whether the object was bigger or smaller than a shoebox. For the other half of the words (i.e., 40 items) participants decided whether the object had a corner. The encoding conditions were blocked, and the order was counterbalanced across participants. Participants made verbal responses, and the experimenter recorded the responses. Following the study phase, participants completed a conceptual priming task similar to the semantic decision task described below, for which participants were presented with a list of words and asked to decide whether the object represented was bigger or smaller than a shoebox. Because many of the AD patients could not easily switch between the two different semantic study tasks and the test phase decision, the results of this conceptual priming task are not described in the current article.

During the recognition test phase, participants were presented with words on the computer screen and were asked to decide whether the word had been previously presented in the experiment (*old*) or if it had not (*new*). Sixty items were presented, 20 of which had been previously studied in the size encoding condition, 20 of which had been studied in the corner encoding condition, and 20 of which had not been previously studied. However, subsequent recognition memory performance for the words in these two encoding conditions did not differ, $t(38) = 0.95$, and performance was collapsed across these two conditions. Responses were made verbally, and the experimenter recorded each response. The recognition memory test included only items from the study phase and did not include any items that were seen in the preceding conceptual priming task.

For the category exemplar generation task, all items were presented individually on index cards. During the study phase, participants were presented with words and decided whether the word represented an item that was man-made or an item that was natural. Responses were made verbally, and the experimenter recorded each response. An exemplar generation test followed in which participants were presented with category names and were asked to quickly provide the first four examples of the given category that came to mind. All responses were made verbally and were recorded by the experimenter. Participants were given 90 s to generate their responses to each category name. The exemplars for the unstudied categories were used as a baseline measure of performance on this task.

For the semantic decision task, stimuli were presented on a laptop computer and participants responded with computer-monitored response buttons. At study, participants were presented with a mixed list of 80 items, half of which were presented as words and half of which were presented as pictures. The question *Is it bigger than a shoebox?* was printed below each item. Participants responded by pressing one of two labeled and differently colored response buttons (i.e., *yes* = green vs. *no* = red). The test was self-paced, but participants were told to respond as quickly and accurately as possible. They were then presented with a test phase, which was identical to the study phase except that 120 items were presented, 80 of which were repeated from the study phase (i.e., 40 of these items repeated in the same format as studied, and 40 items repeated in the opposite format as studied). Response times greater than 30 s were not recorded by the computer, and consequently such responses were not included in the analyses.

# Results

The significance level for all tests was $p < .05$, and all $t$ tests were two-tailed, unless otherwise noted. Separate-variance $t$ tests were used rather then pooled-variance $t$ tests when Levene's (1960) test for equality of variance reached the .05 significance level, indicating unequal variance between groups. All analyses were conducted on 20 AD and 19 control participants.

### Recognition

The mean hits and false alarms for the AD patients were .53 and .37 respectively, compared with .83 and .08, respectively, for the control participants. A comparison of the corrected recognition scores (hits minus false alarms) indicated that the AD patients exhibited a significant recognition memory impairment relative to the controls, $t(37) = -13.87$.

### Category Exemplar Generation

The AD patients generated significantly fewer target items to studied category cues ($M = 4.45$, $SD = 2.09$) than did the controls ($M = 6.47$, $SD = 3.69$), $t(28) = -2.09$, suggesting that the AD patients exhibited a deficit on the exemplar generation test. The two groups generated similar numbers of target items to nonstudied category cues ($M = 2.05$, $SD = 1.36$ for AD patients; $M = 2.11$, $SD = 1.49$ for controls), $t(37) = -0.12$. Because there were no significant differences in baseline performance to nonstudied category cues, priming scores were derived by subtracting the new item performance from the old item performance. The magnitude of the priming effect observed in the AD patients was approximately half the size of that observed in the control group, and this difference was significant using a one-tailed test, $t(37) = -1.92$. The results indicate that the AD patients demonstrated a priming deficit on the exemplar generation test.

### Semantic Decision

Only decisions that did not exceed 2 *SD*s from the participant's mean response time within each study–test condition were included in the analysis. A preliminary analysis indicated that the study and test formats (picture vs. word) did not significantly influence performance; thus, the responses were collapsed across these conditions. This pattern of results was consistent with that found by Vriezen et al. (1995) except that in their study, pictures were found to be classified faster than words. However, the power associated with these null effects in the current study was low; it is possible that with greater power, an overall effect of study–test format, and an interaction of this variable with participant group, could be obtained. On average AD patients made a greater percentage of errors (i.e., incorrect decisions about the relative size of an item compared with a shoe box) than the controls, 15% compared with 10%, respectively, and this difference was significant, $t(26) = 3.50$. Additional analyses were conducted in which the incorrect responses were excluded from the analyses; however, these analyses did not change the pattern of the results and thus are not reported. Moreover, subsequent analyses were conducted on median response times, and with one exception, mentioned below, this analysis led to the same conclusions as did the mean latency analyses and thus is not reported.

The mean response times for old and new items are presented in Table 1. An examination of Table 1 shows that AD patients were approximately 3 times slower than the controls when responding to new items, $t(19) = 3.42$, indicating that the levels of baseline performance among the two groups were not comparable. To determine whether the slower response times demonstrated by the AD participants influenced the priming effects in the semantic decision test, we conducted a regression analysis to learn whether the magnitude of the priming effect was correlated with the response time for new items (Figure 1). An analysis conducted on the data collapsed across participant group indicated that the priming effects were significantly correlated with the new item response time ($R^2 = .41$), such that those participants who had the longest response times had the largest priming effects. The same pattern of results was obtained when the two groups were examined separately ($R^2 = .53$ for AD patients; $R^2 = .79$ for controls).

Given that the AD patients exhibited longer response times than the controls and that the priming effects in the semantic decision test were influenced by baseline response time, standard priming scores (old minus new response time) could not be used to compare the priming effects in the two groups. For this reason we analyzed performance using proportional priming effects and residualized priming scores (for a discussion, see Chapman, Chapman, Curran, & Miller, 1994). Because no one method for correcting for baseline differences between groups has been universally accepted, both of these analytical methods were used. Note, however, that we also present the analysis of the absolute priming scores to facilitate comparison with previous studies.

An analysis of variance conducted on the mean response time data revealed an effect of item type (old vs. new), $F(1, 37) = 8.11$, $MSE = 40{,}844$; an effect of group $F(1, 37) = 12.23$, $MSE = 7{,}401{,}421$; and a nonsignificant Item Type × Group interaction ($F < 1$). Thus, this analysis suggests that the priming effects of the AD patients and controls did not differ in magnitude but that the two groups did differ in response time.

The proportional priming effects were calculated as the difference in response time for old and new items divided by the new item response time (see Figure 2). For the

Table 1
*Mean Response Times and Standard Deviations (ms) With Absolute Priming Scores (Response Time to New Items Minus Response Time to Old Items) for Alzheimer's Disease (AD) and Control Groups on the Semantic Decision Task*

| Group | Old | | New | | New minus old | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| AD | 3,090 | 2,540 | 3,229 | 2,793 | 139 | 365 |
| Control | 943 | 282 | 1,065 | 419 | 122 | 164 |

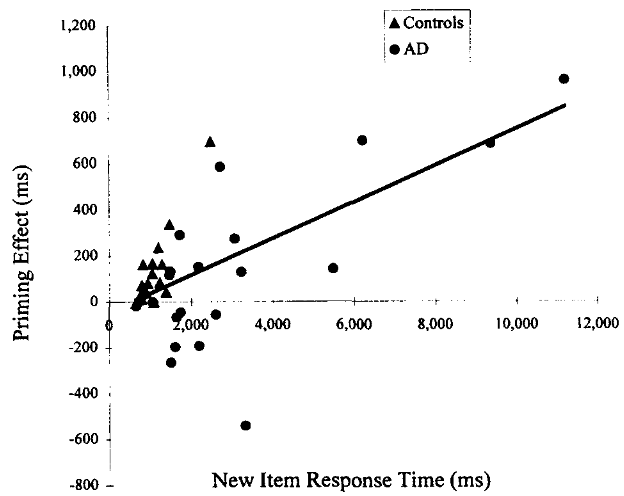


*Figure 1.* Mean priming effects (response time to nonstudied items minus response time to studied items) plotted as a function of new item response time for each Alzheimer's disease (AD) and control participant on the semantic decision task.

proportional priming scores, planned comparisons indicated that the proportional priming effect was not significant for the AD patients, $t(19) = 0.82$, but was significant for the controls, $t(18) = 4.89$. A comparison of the proportional priming effects revealed that the AD group exhibited a significant deficit in conceptual priming compared with the controls, $t(37) = 2.46$. Note that for the analysis of median response times rather than the means, the AD group also exhibited a smaller proportional priming effect than the controls, but the effect failed to reach the level of significance, $t(37) = 1.58$.

As a final analysis, the groups were compared on the residuals of priming difference scores with overall performance partialed out, using the regression equation for the performance of the control group (see Chapman et al., 1994). The analysis of the residual scores was performed in the following manner. First, the mean response time to old items and the mean response time to new items were summed for each participant. Then, a regression analysis was conducted to determine the relationship between the total response time and the priming effect for the control group. This analysis revealed a line of best fit with the slope $b = .20$ and the intercept $a = -275.42$. This equation was then used to determine an expected priming score for each participant, given his or her total response time. Finally, the difference between each participant's expected priming score and observed priming score was calculated. The comparison of those difference scores for the AD and control groups revealed that the AD group had significantly larger difference scores than the control group, $t(19) = 4.40$. For the control group there was only a small difference between the observed mean priming score and the predicted mean priming score, 122 ms and 127 ms, respectively. In contrast, the observed priming score for the AD patients was much smaller than the expected priming score, 139 ms and 989 ms, respectively. Thus, the observed priming scores of the AD patients were significantly smaller than that which was predicted from the priming effect of the control group, indicating that AD patients exhibited a priming deficit in the semantic decision task.

An examination of Figure 1 indicates that there were several AD patients who exhibited extremely slow response times to new items. To determine whether the results were biased by the inclusion of these slow responders, we removed the 4 slowest AD patients from the analysis. Note that the MMSE scores for these 4 patients were between 15 and 19, which was slightly lower than the average MMSE score for the remaining 16 AD patients ($M = 20.88$, $SD = 3.03$). Removing these 4 patients did not alter the conclusions, and the AD subgroup exhibited a deficit in priming relative to the controls as measured by proportional priming, $t(33) = 2.68$, and by residualized priming scores, $t(16) = 4.60$.

In sum, the absolute priming scores for the AD patients did not differ from those for the control participants. However, the AD patients were significantly slower on the semantic decision test than were the control participants. When we took the differences in response times into account by examining the proportional priming scores and the residualized priming scores, the results indicated that the AD patients exhibited a significant deficit in priming relative to the control participants on the semantic decision task.

## Discussion

The current study examined conceptual priming on the semantic decision task in a group of mild to moderate AD patients and in a group of healthy age-matched controls to determine whether the conceptual implicit memory deficits previously reported in AD patients would be observed in a task that did not require word production. AD patients were significantly slower when responding to the new items than

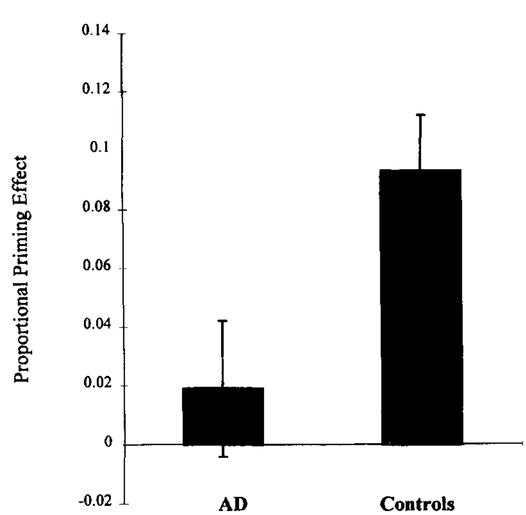


*Figure 2.* Mean proportional priming effects for the Alzheimer's disease (AD) and control groups on the semantic decision task.

were the controls on this task, and slow responses were significantly associated with increases in the absolute priming effects. When we accommodated differences in baseline performance by examining proportional and residual priming scores, the results indicated that the AD patients exhibited a significant deficit in conceptual priming on the semantic decision test. Thus, the conceptual implicit memory deficits observed in AD patients cannot be attributed completely to difficulties with word production in those patients. The current study also found that these same AD patients showed deficits on a category exemplar generation test and on a recognition memory test.

The current results add to a growing body of research indicating that conceptual implicit memory performance is disrupted in AD. The finding of reduced priming on the exemplar generation test is consistent with several previous studies using this test procedure (e.g., Gabrieli et al., 1999; Monti et al., 1996; Vaidya et al., 1999) and with several studies using the word-association task (e.g., Brandt et al., 1988; Carlesimo et al., 1995; Huff et al., 1988; Salmon et al., 1988). However, as we discuss below, it is important to note that some studies have reported normal conceptual priming among AD patients on these same tasks (e.g., Maki & Knopman, 1996; Vaidya et al., 1999).

Measures of conceptual priming that do not involve word production (e.g., speeded response time tasks, such as the semantic decision test) have been less well studied in AD patients. However, a recent study that used a test procedure similar to that of the current study (published after the current study was completed) reported that AD patients show normal conceptual priming (Gabrieli et al., 1999). In that study, conceptual priming was measured using a category verification task in which participants made yes–no decisions to questions regarding category membership of test items (e.g., "Is this a type of vegetable?"). They found that the AD patients exhibited normal priming on the category verification task, in both absolute priming scores and in proportional priming scores.

Procedural differences between the Gabrieli et al. (1999) study and the current study may have played a role in producing the different outcomes across studies. For example, the semantic decision task used in the current study required participants to make judgments about the size of objects, whereas in the task used by Gabrieli et al., participants were required to make judgments about category membership. The semantic knowledge assessed in the size judgment task may be more complex or reflect more distant associations than knowledge assessed in the category verification test. For instance, the size judgment task may have required additional visualization processes that were not required by the categorization task. Alternatively, category information may be more closely related to the item than is size information. This is consistent with the finding that AD patients exhibit normal free-association priming for highly associated items (Vaidya et al., 1999) but exhibit reduced priming for less highly associated items (Brandt et al., 1988; Carlesimo et al., 1995; Huff et al., 1988; Salmon et al., 1988). The claim that the size judgment task is more complex or requires more distant associational information is also consistent with the observation that the response times observed in the current study were longer than those reported for the category verification task (Gabrieli et al., 1999) for both elderly controls and AD patients. Another difference between the two studies was that Gabrieli et al. (1999) measured response time by voice activated relay, whereas a two-choice button press was required in the current study. This type of manual response may have been particularly difficult for the AD patients (for a related discussion, see Ober, Shenaut, & Reed, 1995).

The pattern of normal and abnormal conceptual priming observed in AD patients is complex. Although several dichotomies have been proposed to account for the priming deficits found with AD patients, none can explain all of the existing data (for a review, see Fleischman & Gabrieli, 1998). The current results demonstrated that a simple production–identification distinction does not accurately characterize the priming results found in AD. That is, removing the word-production requirement of the conceptual implicit memory test, as we did with the current semantic decision test, did not eliminate the conceptual priming deficit often found with AD patients. The distinction also does not explain why AD patients appear to perform normally on some tests that do require word production (e.g., Maki & Knopman, 1996).

Related to the identification–production distinction, Vaidya et al. (1997) suggested that *competitive* conceptual priming is impaired in AD but that *noncompetitive* conceptual priming is spared in AD. In noncompetitive tasks the test cue directly guides the retrieval of conceptual knowledge. That is, direct access is made to the target concept, and alternative concepts are not activated. The semantic decision task would presumably be an example of a noncompetitive task because there are no competing items for a given test item. In contrast, in competitive conceptual memory tests the test cue activates more than one semantic representation. That is, the test cue is semantically related to the target item in addition to other conceptual alternatives. For example, word association and exemplar generation tests are competitive because there are several potential items competing for a response. Although several recent findings are consistent with the hypothesis that only competitive conceptual implicit memory is disrupted in AD (e.g., Gabrieli et al., 1999; Vaidya et al., 1999), the results of the current study do not support this proposal, because the AD patients showed deficits on the semantic decision test, which is a noncompetitive conceptual task.

A consideration of the existing literature on conceptual implicit memory in AD indicates that there may not be a simple distinction that accounts for when AD patients will or will not exhibit conceptual priming deficits. Rather, it appears that several different factors may conspire to lead to a deficit in conceptual implicit memory performance in AD patients. First, several studies indicate that encoding conditions play a critical role in determining whether AD patients will exhibit a priming deficit. For example, deficits are observed when items are encoded under deep but not shallow encoding conditions (Monti et al., 1996) and under read compared with generate conditions (Maki & Knopman, 1996). Thus, deficits in conceptual priming could be due in part to an underlying encoding deficit that results in AD patients experiencing a less rich encoding episode relative to that of the controls in some conditions. Second, the nature of the semantic information that is assessed in a memory task also appears to play a critical role in the priming performance of AD patients. As mentioned previously, AD patients do not exhibit deficits in the free-association task if the words are all high associates (Vaidya et al., 1999), but they do exhibit deficits when the words are more distantly related (Brandt et al., 1988; Carlesimo et al., 1995; Huff et al., 1988; Salmon et al., 1988). Similarly, in the size judgment task used in the current study, AD patients did exhibit a deficit, but in a similar task in which category membership information was tested, AD patients were not impaired (Gabrieli et al., 1999).

The encoding deficits and difficulties with more distant semantic relationships may be related to attentional deficits in AD. That is, poor encoding may occur in AD patients because they lack the attentional resources to adequately encode items (see Monti et al., 1996), and tasks that tap more distant semantic relationships may rely more heavily on the attention processes that are compromised in AD (see Nebes, 1992; Zec, 1993, for reviews of cognitive function in AD).

The use of explicit memory may also play a role in the deficits observed in AD patients. The control participants may use their superior explicit memory to improve their performance on the conceptual priming tasks. Although some studies have indicated that explicit memory cannot completely account for the observed deficits in AD (e.g., Maki & Knopman, 1996; Vaidya et al., 1999), it may play a role in other studies. The semantic decision task used in the current study was a speeded response time measure, which is thought to be less affected by explicit memory than other procedures (Vriezen et al., 1995). However, the contribution of explicit memory to performance on these tasks has never been directly examined. Future studies examining the contribution of explicit memory to speeded conceptual implicit memory tests will be important.

The current finding of a deficit in conceptual implicit memory performance in AD patients contrasts with the finding that AD patients perform normally on semantic priming tasks, at least when automatic semantic priming processes are being assessed (e.g., Ober & Shenaut, 1995; Shenaut & Ober, 1996). In semantic priming tasks participants are found to make faster responses to target items if a semantically related item immediately precedes the item. Preserved semantic priming has been taken as evidence that semantic knowledge structures are intact in early AD (see Nebes, 1989; Ober & Shenaut, 1995). Semantic priming effects are relatively short-lived (i.e., seconds) and involve interitem associations. In contrast, conceptual priming is relatively long-lived and involves repeated, semantic-level activation of the same concept. The extant pattern of findings seems to indicate that the processes involved in semantic priming versus conceptual priming, and also within general types of priming paradigms, are different and not uniformly affected by AD.

An impairment in conceptual implicit memory performance among AD patients is consistent with the pathology of the disease. Evidence suggests that conceptual processing may involve the temporal and frontal lobes (Gabrieli et al., 1994; Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996; Wagner, Desmond, Demb, Glover, & Gabrieli, 1997). Temporal lobe structures show the pathological markers of AD early in the course of the disease, and the parietal and frontal lobe structures are usually affected at the more moderate stages of the disease (e.g., Damasio, Van Hoesen, & Hyman, 1990; Jagust, 1996). If conceptual priming tasks tap knowledge that is represented or processed in the temporal and frontal lobes, the finding of deficits on these tasks is consistent with the pattern of disease pathology. However, findings of spared performance on some conceptual priming tasks (e.g., Gabrieli et al., 1999; Vaidya et al., 1999) and on semantic priming tasks (e.g., Balota, Watson, Duchek, & Ferraro, 1999; Shenaut & Ober, 1996) suggest that future studies investigating the involvement of specific brain areas in the various tasks that involve access and use of different semantic knowledge are needed.

In sum, the current study demonstrates that AD patients can exhibit deficits on conceptual priming tasks that do not require word production, such as the semantic decision task, thus indicating that the conceptual implicit memory deficits observed in AD patients cannot be attributed entirely to word production deficits. The results converge with the findings of several previous studies indicating that AD patients often exhibit deficits on conceptual implicit memory tests. Nonetheless, some studies have found normal conceptual priming among AD patients on these tasks, and it is not yet clear which factors play a role in the memory deficits that are observed. The current results, taken along with previous studies suggest that several factors, including the encoding conditions and the type of materials, play an important role in determining whether conceptual implicit memory deficits are observed in AD patients.

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