Journal of the International Neuropsychological Society (1999), **5**, 659–667.

Effects of structural similarity and name frequency on picture naming in Alzheimer's disease

SHARON L. THOMPSON-SCHILL,[1] JOHN D. E. GABRIELI,[2,3] AND DEBRA A. FLEISCHMAN[3]

[1]Department of Psychology, University of Pennsylvania
[2]Department of Psychology, Stanford University
[3]Department of Neurological Sciences, Rush-Presbyterian-St. Luke's Medical Center

(RECEIVED January 6, 1999; REVISED April 5, 1999; ACCEPTED June 1, 1999)

Abstract

Impairments to either perceptual or word-retrieval processes have been hypothesized to explain confrontation naming impairments in patients with Alzheimer's disease (AD). This study measured the effects of structural similarity, which affects perceptual processing, and name frequency, which affects word retrieval, on naming latency and accuracy in 16 AD patients and 16 age-matched controls. AD patients named pictures more slowly and made more errors than control participants. Their naming accuracy was disproportionately affected by name frequency, but not by structural similarity. The findings indicate that the processing of structural properties of objects is unaffected in early-stage AD, and suggest that word-retrieval impairments underlie the naming deficit in AD. (*JINS,* 1999, *5*, 659–667.)

Keywords: Alzheimer's disease, Anomia, Frequency, Perceptual

INTRODUCTION

An impairment in the ability to name objects is one of the earliest symptoms of Alzheimer's disease (AD); furthermore, the severity of the overall dementia in AD is highly correlated with the degree of impairment on a confrontation naming task (Skelton-Robinson & Jones, 1984). The specific nature of the deficit underlying the naming impairment is the subject of some debate. There is general agreement that picture naming requires at least two distinct and sequential stages of (1) perceptual processes that recognize the structure of the object or picture, and (2) word-retrieval processes that include the semantic, lexical, and phonological operations involved in producing the object's or picture's name. There is, however, less certainty about whether the picture-naming deficit in AD reflects either impaired object recognition or impaired word retrieval. A perceptual impairment would cause misidentification of pictures based on incomplete or inaccurate visual information; errors should reflect visual similarities between objects and should be affected by perceptual factors, such as detail or visual quality. A word-retrieval impairment would cause errors that reflect nonperceptual factors, such as word meaning or name frequency. Several studies have examined the types of errors that AD patients make and the factors that influence error rates in order to distinguish between perceptual and word-retrieval impairments.

Evidence that naming errors in AD reflect visual confusability and visual quality of the stimuli argues for a perceptual impairment in AD. In one study, many of the incorrect responses (55%) given by AD patients on a confrontation naming task were visually similar to the presented objects (e.g., calling a thimble a cup; Rochford, 1971). In a second study, AD patients were more likely to correctly name an object if they were able to use nonvisual sensory information (e.g., touch) to aid their identification (Barker & Lawson, 1968). In another study, the amount of available perceptual information was reduced across four conditions by presenting an actual object, a black-and-white photograph of the object, a line drawing of the object, or a masked line drawing of the object (Kirshner et al., 1984). AD patients, but not control participants, made more errors as available perceptual information was reduced. Shuttleworth and Huber (1988) replicated the increased sensitivity of AD patients to the amount of available perceptual information. Furthermore, the presentation of actual objects significantly re-

Reprint requests to: Sharon L. Thompson-Schill, 3815 Walnut Street, Department of Psychology, University of Pennsylvania, Philadelphia, PA 19104-6196. E-mail: thompson@psych.upenn.edu

duced the proportion of visually similar errors made by AD patients. Thus, naming errors decreased when the likelihood of perceptual misidentification was reduced.

Other studies argue that naming errors in AD are the result of a word-retrieval impairment despite adequate perception of a picture. These studies have found a high proportion of semantically related errors (Bayles & Tomoeda, 1983; Martin & Fedio, 1983) and difficulty discriminating among exemplars in the same semantic category (Huff et al., 1986; Skelton-Robinson & Jones, 1984). Item-specific deficits have been reported across several different tasks and modalities (Flicker et al., 1987; Huff et al., 1988). Within-item consistency, particularly with tasks that require no perceptual processing (e.g., exemplar generation), suggests a semantic impairment in AD. Also, many studies of AD patients have reported that the probability of a naming error varied with the frequency of the name: The lower the frequency of the object, the more likely an AD patient was to name the picture incorrectly (Kirshner et al., 1984; Skelton-Robinson & Jones, 1984). Low-frequency words are more difficult to retrieve (i.e., take longer to retrieve) than high-frequency words, and the disproportionate AD deficit with low-frequency words may reflect deficits in controlled or effortful word-retrieval processes (Ober & Shenaut, 1995). Although these studies have led to a variety of interpretations about the status of semantic representations and controlled retrieval processes in AD, they are similar in so far as they indicate a nonperceptual basis for the naming impairment in AD.

There are, however, two further issues in picture naming that go beyond a dichotomy between perceptual and word-retrieval processes and may both be relevant to AD. First, there is evidence that different kinds of pictures may invoke different kinds of knowledge represented in separable brain regions. Second, perceptual and word-retrieval processes may interact during picture naming rather than occur in a strictly serial fashion. Evidence that the impairment in the ability to recognize and name visual objects can vary across categories of semantic knowledge comes from patient studies that report specific inabilities to name either living objects (Warrington & Shallice, 1984) or nonliving objects (Warrington & McCarthy, 1983, 1987). Rather than interpreting these results as evidence for separate brain locations for semantic knowledge about living and nonliving objects, Warrington and colleagues suggested that the organization of semantic memory is modality-specific. The bulk of our experience with many living things is *sensory*. Further, various four-legged animals, or birds, or insects tend to look structurally similar and must be distinguished by relatively subtle structural attributes. In contrast, the bulk of our experience with manufactured objects is *functional*. Further, nonliving things, especially manufactured items such as appliances, or weapons are structurally distinct and can be identified based on relatively few perceptual features. The sensory–functional hypothesis explains these category-specific impairments in terms of the differential weighting of visual and motor information in the representation of knowledge about living and nonliving things (Farah & McClelland, 1991).

Convergent evidence from three sources favors the sensory–functional hypothesis over the living–nonliving hypothesis of category-specific knowledge deficits. First, the sensory–functional hypothesis is more consistent with the sensorimotor organization that is already known to exist in the brain. There is some evidence for sensorimotor organization of semantic representations as well. For example, some aphasic patients have a specific impairment in the ability to describe the function of an object despite normal ability to describe the appearance or category of the object (Goodglass et al., 1986). The sensory–functional hypothesis also receives support from neuroimaging studies of normal populations (Martin et al., 1995). Second, the sensory–functional hypothesis explains exceptions to the living–nonliving distinction that have been observed in clinical reports; for example, a patient with a selective impairment of living things was also impaired on two nonliving, but structurally similar categories: gemstones and fabrics (Warrington & Shallice, 1984). Finally, Farah and McClelland (1991) demonstrated that a computational model of semantic knowledge with only modality-specific components can account for selective impairments in the knowledge of living and nonliving things. Support for a neural basis of this model was provided by a neuroimaging study of visual and nonvisual knowledge of living and nonliving things (Thompson-Schill et al., 1999). These three lines of evidence suggest that a specific impairment in the ability to name living things may reflect the greater degree of structural analysis required to distinguish living objects from one another, rather than a fundamental impairment in the representation of living things.

Several studies have addressed the possibility of category-specific naming impairments in AD. According to the sensory–functional hypothesis, a perceptual impairment would result in a disproportionately higher error rate for living than for nonliving things in AD patients relative to controls due to the high visual similarity of living things. This result was reported by Silveri et al. (1991) on a confrontation naming task using color pictures of living and nonliving objects. AD patients performed significantly worse on the living than on the nonliving pictures, in contrast to the controls who showed no such difference. The failure to find a difference for controls in this study, however, is difficult to interpret given the very high accuracy rate (over 99%). Thus, this study could not rule out the possibility that living things are generally harder to identify than nonliving objects.

Other reports argue against a disproportionate impairment of living things in AD. Hodges et al. (1992) report no differences between living and nonliving items on a confrontation naming task for either AD patients or control participants. Montanes et al. (1995) report more errors naming line drawings of living things than of nonliving things in both AD patients and normal controls; the interaction between semantic category and patient group was not reported, so the extent of a disproportionate impairment for living things in AD is unclear. In a second experiment mea-

suring naming accuracy for color pictures, Montanes et al. found no differences between living and nonliving items for either AD patients or control subjects. Thus, these studies provide some challenge to the claim that AD patients have a specific impairment in the ability to name living things.

There is also evidence that perceptual and word-retrieval processes are interactive during the course of picture naming (Humphreys et al., 1988) such that information about structural properties of an object may start to affect word-retrieval processing before the perceptual analysis is completed. Humphreys et al. (1988) manipulated structural similarity of pictures orthogonally with name frequency. Structural similarity, measured by degree of overlap between line drawings of objects within a semantic category, should affect the processing time required during the structural analysis of the picture. Conversely, the frequency of the name of the picture, which has been shown to have a robust effect on naming latency (Oldfield & Wingfield, 1965), should affect the processing time required during word retrieval. Humphreys et al. found that high frequency pictures were named faster than low-frequency pictures for structurally distinct items, but not for structurally similar items. The behavioral interaction between a factor (structural similarity) that influences perceptual processing and another factor (name frequency) that influences word retrieval supports an interactive cascade model of picture naming. For pictures that are structurally distinct, the main limitation in naming may be the frequency of the picture name. Pictures that are structurally similar may coactivate a number of potential names, and the main limitation is resolution of the object's structural identity (the co-activation of multiple names renders them all available as soon as object recognition is complete and therefore eliminates word frequency as a factor in naming latency).

The present experiment examined the interaction between perceptual processing and word-retrieval in AD using an orthogonal manipulation of structural similarity and name frequency. Both naming latency and accuracy were measured to provide a more sensitive measure of the differences between living and nonliving items; in all previous studies in which category-specific effects were compared between AD patients and elderly control participants, the control participants performed at ceiling on accuracy measurements (Hodges et al., 1992; Montanes et al., 1995; Silveri et al., 1991).

The orthogonal manipulation of structural similarity and name frequency allowed for assessment of three possible sources of naming impairment in AD. If the naming deficit in AD is perceptual, patients should be impaired on structurally similar items, which require more detailed perceptual processing, irrespective of name frequency. If the naming deficit is due to word retrieval, patients should be impaired on low name-frequency items, irrespective of structural similarity. Finally, if the deficit is one of transmission between perceptual processing and word retrieval, AD patients should show an abnormal interaction between structural similarity and name frequency.

METHODS

Research Participants

Sixteen patients with a clinical diagnosis of AD and 16 age-matched controls were recruited for the study. Each AD patient received a standard diagnostic evaluation that included a medical history, neurological examination, neuropsychological testing, MRI, electrocardiogram, chest x-ray, and routine blood tests. All patients met clinical criteria for AD as outlined by the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) and the Alzheimer's Disease and Related Disorders Association (ADRDA) Work Group (McKhann et al., 1984). The criterion that AD patients demonstrate episodic memory impairment was operationally defined in this study as a score of 5 or less on the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) delayed Word List Recall measure (Morris et al., 1989). Patients with moderately severe dementia, defined as a Mini-Mental State Examination (MMSE; Folstein et al., 1975) score below 17, were excluded.

Controls for the AD patients were recruited from patient spouses and a pool of older hospital volunteers. Control evaluations consisted of a medical history and administration of the MMSE and CERAD Word List procedure. Inclusion required an MMSE score of 27 or greater and delayed Word List Recall score of 6 or greater. The exclusion criteria were the same as those for the AD group. The AD patients and their controls did not differ significantly in age ($p > .30$). Control participants had more education than did AD patients [$t(29) = 3.54$; $p < .01$]. Table 1 provides demographic and psychometric information for the AD patients and the control participants.

Materials

The stimuli were the complete set of 76 pictures used by Humphreys et al. (1988). In this set, half of the items were drawn from categories where exemplars tend to be structurally similar (*birds*, *insects*, *animals*, *vegetables*, and *fruits*) and half were selected from categories where exemplars tend to be structurally distinct (*clothing*, *household items*, *furniture*, *vehicles*, *tools*, *toys*, *body parts*, *jewelry*). As noted in the Introduction, living things tend to be structurally more similar to each other than do nonliving things; thus it was unavoidable that the structurally similar categories were all groups of living things. The relevance of the living–nonliving dichotomy for the present study is addressed in the Discussion.

To quantify the differences between structural similarity for the items in this set, Humphreys et al. (1988) obtained ratings of attribute overlap (i.e., number of common parts for exemplars from each category) and contour overlap (i.e., average percentage contour overlap of normalized line drawings between exemplars of the same category); items in the structurally similar categories had more common attributes

https://doi.org/10.1017/S1355617799577084 Published online by Cambridge University Press

Table 1. Demographic and psychometric information

Group	Age (years)	Education (years)	MMSE	CERAD measure of recall	
				Immediate[a]	Delayed[b]
Control ($N = 16$)					
M	70.9	15.5*	28.9**	22.2**	7.8**
SD	5.2	1.7	1.0	2.2	1.4
Alzheimer's disease ($N = 16$)					
M	73.2	12.8[c]	22.9	12.1	2.3
SD	5.2	2.5	2.6	4.0	1.8

Note. CERAD = Consortium to Establish a Registry for Alzheimer's Disease; MMSE = Mini-Mental State Examination.
[a]Maximum score = 30. [b]Maximum score = 10. [c]Education data was unavailable for 1 AD patient.
*$p < .01$. **$p < .001$.

and a higher degree of counter overlap with other items in the same category than did items in structurally distinct categories. The line drawings of each item were obtained from the Snodgrass and Vanderwart (1980) standardized set, and structurally similar and structurally distinct items were matched, on average, on name agreement and image agreement (using the ratings supplied by Snodgrass & Vanderwart).

In each group of 38 items, half of the stimuli were low name-frequency items and half of the stimuli were high name-frequency items (Kucera & Francis, 1967). Consequently, there were 19 items of each of four types of stimuli: (1) low name-frequency and structurally similar (e.g., pear), (2) low name-frequency and structurally distinct (e.g., scissors), (3) high name-frequency and structurally similar (e.g., bear), and (4) high name-frequency and structurally distinct (e.g., clock). The mean name frequencies (occurrences/1,000,000) for structurally similar and structurally distinct low name-frequency items were 2.74 and 2.47, respectively; the mean name frequencies for structurally similar and structurally distinct high name-frequency items were 30.37 and 33.58, respectively. High and low name-frequency items were matched, on average, on contour overlap and complexity (using the ratings supplied by Snodgrass & Vanderwart). Additional details and a complete list of the items used in this experiment can be found in Humphreys et al. (1988).

Procedure

The stimuli were presented using PsychLab software and a Macintosh IIci computer. Each trial began with a central fixation dot for 500 ms, followed by a 500-ms delay. Each picture was presented centrally for an unlimited amount of time. Participants were instructed to quickly and accurately name the picture aloud, and response latencies were measured using a voice-activated relay; incorrect responses were recorded by the experimenter. Subsequent trials were triggered by the participant's response, following a 500-ms intertrial interval. Thus, including the fixation dot at the start of each trial, the interval between the onset of the spoken response and the presentation of the next picture was 1500 ms, which allowed for enough time for participants to complete the pronunciation of their response. The testing session began with a practice block of five items to familiarize participants with the testing procedure. The test block of items consisted of 3 filler items and 76 test items.

RESULTS

Naming Latency

For each participant, the median naming latencies (RTs) for each of the four stimuli types were computed, after discarding trials in which an incorrect response was given or in which a microphone problem produced an inaccurate response time. Median RTs and error percentages are given in Table 2.

The data were analyzed in a $2 \times 2 \times 2$ analysis of variance (ANOVA) with diagnosis (AD or control) as a between-participants factor and structural similarity (similar or distinct) and name frequency (low or high) as within-participants factors. AD patients ($M = 1332.70$ ms) responded more slowly than control participants [$M =$

Table 2. Median correct naming latencies (ms) and percentage errors as a function of structural similarity and name frequency

Group	Structural similarity			
	Structurally similar		Structurally distinct	
	RT	% Error	RT	% Error
Normal control ($N = 16$)				
High frequency	1198	17	979	6
Low frequency	1181	14	1106	10
Alzheimer's disease ($N = 16$)				
High frequency	1463	22	1112	10
Low frequency	1459	25	1297	18

https://doi.org/10.1017/S1355617799577084 Published online by Cambridge University Press

1115.92 ms; $F(1,30) = 4.92$, $p < .05$, $MSE = 305532.95$]. High name-frequency items ($M = 1188.05$ ms) were named faster than low name-frequency items [$M = 1260.58$ ms; $F(1,30) = 4.82$, $p < .05$, $MSE = 34954.46$]. Structurally distinct items ($M = 1123.48$ ms) were named faster than structurally similar items [$M = 1325.15$ ms; $F(1,30) = 20.51$, $p < .001$, $MSE = 63464.43$]. There was a reliable interaction of Name Frequency × Structural Similarity [$F(1,30) = 8.76$, $p < .01$, $MSE = 25367.41$]. Paired t tests (using a Bonferroni corrected alpha rate of .025) indicated that participants named high name-frequency items faster than low name-frequency items for structurally distinct items [$t(31) = 6.05$, $p < .001$, $SE = 25.75$], but not for structurally similar items ($t < 1$). There were no higher-order interactions with diagnosis (all ps $> .20$).

The data were also analyzed over items, after computing the median RT for each item, excluding error trials as before. Additionally, three items (bee, beetle, and tiger) were excluded because they were misnamed by more than 50% of control participants. The data were analyzed in a 2 × 2 × 2 ANOVA with diagnosis (AD or control) as a within-items factor and structural similarity (similar or distinct) and name frequency (low or high) as between-items factors. As with the analysis over participants, there were main effects of diagnosis [$F(1,69) = 40.11$, $p < .001$, $MSE = 32469.49$] and structural similarity [$F(1,69) = 7.21$, $p < .01$, $MSE = 114169.29$]. The main effect of name frequency did not approach statistical significance in the analyses over items ($p > .40$). There was a reliable interaction of Name Frequency × Structural Similarity [$F(1,69) = 4.56$, $p < .05$, $MSE = 114169.29$]. Unpaired t tests (using a Bonferroni corrected alpha rate of .025) indicated that participants named high name-frequency items faster than low name-frequency items for structurally distinct items [$t(36) = 2.60$, $p < .025$], but not for structurally similar items ($t < 1$). There were no higher-order interactions with diagnosis (all ps $> .30$).

Errors

The data were analyzed in a 2 × 2 × 2 ANOVA with diagnosis (AD or control) as a between-participants factor and structural similarity (similar or distinct) and name frequency (low or high) as within-participants factors. There were no indications of a speed–accuracy trade-off. AD patients ($M = 19\%$) made more errors than control participants [$M = 11\%$; $F(1,30) = 9.11$, $p < .01$, $MSE = 6.49$]. The error rate was higher for low name-frequency items ($M = 17\%$) than for high name-frequency items [$M = 13\%$; $F(1,30) = 4.18$, $p < .05$, $MSE = 2.85$]. The error rate was higher for structurally similar items ($M = 19\%$) than for structurally distinct items [$M = 11\%$; $F(1,30) = 40.06$, $p < .001$, $MSE = 2.23$]. There was a significant interaction of Name Frequency × Structural Similarity [$F(1,30) = 5.88$, $p < .05$, $MSE = 1.63$]. Paired t tests (using a Bonferroni corrected alpha rate of .025) indicated a reliable difference between high name-frequency and low name-frequency items for structurally distinct items [$t(31) = 3.50$, $p < .001$, $SE = 0.330$] but not for structurally similar items ($t < 1$). The two-way interaction of Diagnosis × Name Frequency approached significance [$F(1,30) = 2.99$, $p = .094$, $MSE = 2.85$]. No other interactions with diagnosis approached significance (all ps $> .45$).

The data were also analyzed over items; as before, three items were excluded because they were misnamed by more than 50% of control participants. The data were analyzed in a 2 × 2 × 2 ANOVA with diagnosis (AD or control) as within-items factor and structural similarity (similar or distinct) and name frequency (low or high) as between-items factors. As with the analysis over participants, there was a reliable main effect of diagnosis [$F(1,69) = 24.89$, $p < .001$, $MSE = 2.24$]. No other main effects or interactions reached statistical significance. Only one two-way interaction, that of Name Frequency × Diagnosis, approached statistical significance [$F(1,69) = 3.27$, $p = .075$, $MSE = 2.24$].

For both of the above analyses of the error data, the only interaction with diagnosis that approached significance was with name frequency. Paired t tests (over participants, Bonferroni corrected error rate of .025) indicated that for control participants, there was no effect of name frequency on error rate ($t < 1$); however, AD patients made more errors on low name-frequency than high name-frequency items [$t(15) = 2.70$, $p < .025$, $MSE = 0.83$; see Figure 1]. This is

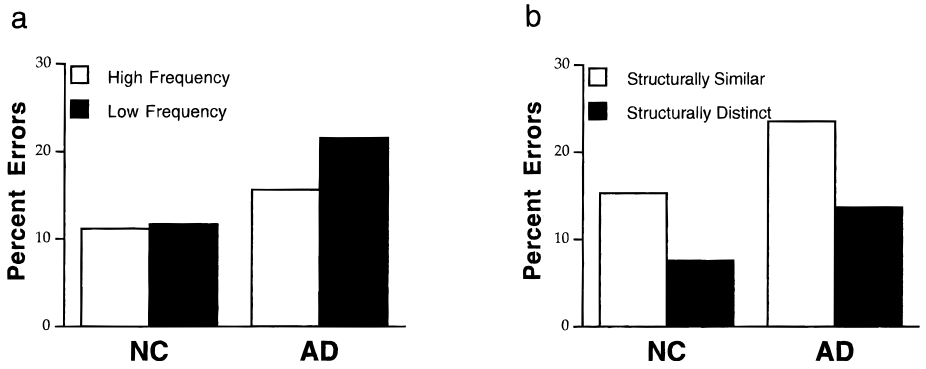

Fig. 1. (a) Percent naming errors as a function of name frequency for 16 AD patients and 16 control participants. (b) Percent naming errors as a function of structural similarity for AD patients and control participants.

https://doi.org/10.1017/S1355617799577084 Published online by Cambridge University Press

in contrast to the comparable effect of structural similarity found in control participants [$t(15) = 4.53$, $p < .01$, $MSE = 0.65$], and in AD patients [$t(15) = 4.50$, $p < .01$, $MSE = 0.84$].

Types of Errors

Errors were classified into six types: (1) superordinate errors, (2) coordinate errors, (3) circumlocutory errors, (4) visual errors, (5) omissions, and (6) other errors. The proportions of each type of error are shown in Table 3. Independent *t* tests were used to compare the proportion of each error type between control participants and AD patients; there were no significant differences for any of the six types of errors (all ps $> .10$).

Education

Two secondary analyses were performed to address the difference in education between AD patients and control participants (see Table 1). First, after accounting for the variance attributable to years of education (using education as a covariate), no changes in the patterns of the data were found. Second, all analyses were repeated on a subset of control participants and AD patients ($n = 12$) who had at least 12 and no more than 16 years of education, and the findings described above for each group were replicated.

Other Variables

A number of other variables about the items used in this experiment may affect picture naming, and could potentially be relevant to explaining naming deficits in AD. Particularly relevant given the results of this study would be any variables that are correlated with name frequency, which therefore might at least partially account for the effects we observed of name frequency on naming accuracy in AD patients. We considered the following variables, provided by Snodgrass and Vanderwart (1980): familiarity, image agreement, name agreement, and complexity. For the 76 items in our set, only one of these variables was significantly correlated with name frequency: *familiarity* ($r = .37$, $p < .01$). No other correlations approached statistical significance (all rs $< .15$).

To examine the effects of familiarity on naming accuracy, error data were analyzed over items, as described above. First, we examined the relative predictive power of both familiarity and name frequency in a multiple regression of these variables on number of errors for each item. Familiarity accounted for more unique variance than did frequency, and was a significant predictor of number of naming errors ($p < .01$). However, when familiarity was included in an ANOVA with diagnosis and structural similarity, as described above for name frequency, an interaction of Familiarity × Diagnosis did not approach significance ($F < 1$). Only the main effect of familiarity approached significance [$F(1,69) = 2.96$, $p < .10$]. Thus, while familiarity is indeed related to naming accuracy, it does not distinguish between AD and control participants and is therefore unlikely to account for the interaction we observed of Name Frequency × Diagnosis.

Table 3. Mean proportion of error types

Error type	Group: Normal control ($N = 16$)	Group: Alzheimer's disease ($N = 16$)
Superordinate ("bug" for "fly")	18	10
Coordinate ("lion" for "tiger")	59	54
Circumlocutory ("it flies" for "plane")	0	1
Visual ("cup" for "thimble")	8	13
Omission	11	17
Other	4	6

DISCUSSION

The goal of this study was to dissociate perceptual and word-retrieval processes in picture naming. Perceptual processes were examined by manipulating the structural similarity of pictures, and word-retrieval processes were examined by manipulating the name frequency of pictures. Independent manipulation of structural similarity and name frequency allowed for the examination of the interaction between perceptual and word-retrieval processes. Participants were faster and more accurate in naming structurally distinct compared to structurally similar pictures, and pictures with high name-frequency compared to low name-frequency. These effects verified the effectiveness of the manipulations of perceptual and word-retrieval processes. In addition, participants were faster and more accurate in naming high name-frequency compared to low name-frequency pictures for structurally distinct items, but there was no effect of name-frequency for structurally similar items. This interaction between structural similarity and name frequency supports the cascade model of picture processing (Humphreys et al., 1988) and shows that the model remains valid across the adult life span.

AD patients were slower and less accurate in naming pictures than were control participants. However, with one exception, there were no interactions between diagnosis and any of the effects described above. For pictures named correctly, AD patients showed a normal effect of structural similarity, a normal effect of name frequency, and a normal interaction of Structural Similarity × Name Frequency on naming latency. Both AD patients and control participants made more errors for structurally similar than structurally distinct pictures; the AD error rate was not disproportionately affected by structural similarity. However, only AD patients made more naming errors for low name-frequency pictures than high name-frequency pictures. This effect of name frequency does not appear to be attributable to other

https://doi.org/10.1017/S1355617799577084 Published online by Cambridge University Press

features of the pictures, such as name agreement or familiarity. The disproportionate effect of word frequency on AD naming errors that we observed mirrors frequency effects reported elsewhere not only with picture naming (e.g., Kirshner et al., 1984), but also with lexical decision tasks (e.g., Ober & Shenaut, 1988).

The normal effect of structural similarity in AD patients indicates that structural analysis of objects is unaffected in early-stage AD. Previous studies of picture naming have argued for preserved structural analysis in AD on the basis of *post-hoc* error classifications (Bayles & Tomoeda, 1983; Martin & Fedio, 1983), a useful but inevitably subjective categorization. The only direct assessment of the relation between perceptual processes and picture naming measured perceptual processes via discrimination of irregular polygons (Huff et al., 1986). Although discrimination of abstract forms provides a good test of perceptual ability, it may or may not provide a measure of the same processes involved in perceiving meaningful objects. The present study used objective, structural properties of pictures to assess perceptual processes, and thus shows directly that AD patients retain the processes involved in the structural analysis of meaningful pictures.

If a perceptual impairment explains the AD naming deficit, then AD patients should show a disproportionate difficulty with items that are more visually confusable. In this experiment, neither the latency nor the accuracy of AD patients was disproportionately affected by structural similarity. If deficient transmission between perceptual processing and word retrieval explains the AD naming deficit, then the AD patients should show an abnormal interaction of Structural Similarity $\times$ Name Frequency. AD patients showed the same interaction of Structural Similarity $\times$ Name Frequency as did control participants. If a word-retrieval impairment explains the AD naming deficit, then AD patients should show a disproportionate impairment on low name-frequency items. In this experiment, AD patients made significantly more errors for low name-frequency items relative to high name-frequency items; this dissociation did not occur for the control participants. Thus, a word-retrieval deficit is the most likely explanation of the AD naming impairment. The present study, however, cannot determine whether the word-retrieval deficit is better characterized as item-specific degradation of semantic knowledge (e.g., Huff et al., 1988) or as impairment of controlled word retrieval (e.g., Ober & Shenaut, 1995).

The structurally similar items used in this experiment were drawn from categories of living things, and the structurally distinct items were drawn from categories of nonliving things. The effect of structural similarity on latency and accuracy in both control participants and AD patients indicates that living things are generally more difficult to name than nonliving things. The finding that AD patients are normally influenced by structural similarity suggests that AD patients do not have a disproportionate impairment in the knowledge of living things. The discrepancy with a previous finding of category-specific deficits in AD (Silveri et al., 1991) likely reflects a ceiling effect in the performance of control participants that may have obscured the finding that living things are more difficult to name. Montanes et al. (1995) reported conflicting results about whether accuracy is lower for living things; however, our data are consistent with their apparent failure to find a disproportionate impairment in naming accuracy in AD patients.

In contrast to the similar effect of structural similarity on naming in AD patients and control participants, name frequency had a differential effect on AD patients relative to control participants. The differential effect of name frequency was found for naming accuracy, but not for naming latency. Response times often mirror accuracy rates, but in the present study there was a sharp boundary between low name-frequency pictures that were named correctly and those that were named incorrectly. When a picture was named correctly, AD patients were no more affected by name frequency than were control participants. However, AD patients were more likely to name incorrectly low-frequency items than high-frequency items.

The present findings may not be generalizable to more severely demented patients or to early-stage patients who present clinically with visuospatial impairment. The relative proportions of visual and semantic errors have been shown to change as the disease progresses (Huff et al., 1986; Martin & Fedio, 1983), suggesting that there may be two distinct deficits with different time courses. Likewise, Gonnerman et al. (1997) suggested that the degree of category-specific deficits in AD may change (and even reverse) as the disease progresses, a hypothesis which has been supported by subsequent computational models of these impairments in AD (Devlin et al., 1998). In our study, the same pattern was found for patients with both moderate and mild dementia; however, as the dementia becomes more severe, AD patients may experience additional impairments of structural processing. Also, some early-stage patients with disproportionate visuospatial problems may have deficits in perceptual processing of pictures (Montanes et al., 1995; Shuttleworth & Huber, 1988) but, because these patients represent a minority of AD cases, our results are generalizable to most early-stage AD patients.

The present results reveal a dissociation between perceptual and word-retrieval processes required for picture naming. The perceptual processes required to analyze structural features of pictures were preserved in AD patients, but word-retrieval processes, as indexed by the effects of name frequency, were impaired. The dissociation between perceptual and word-retrieval processes may extend beyond object recognition to implicit memory processes. For example, forms of repetition priming that rely on structure-based processing (e.g., perceptual identification) are often intact in AD (Fleischman et al., 1995; Gabrieli et al., 1994; Keane et al., 1991, 1994), including picture-naming priming with stimuli overlapping with those used in the present study (Park et al., 1998). In contrast, kinds of repetition priming that rely on effortful retrieval (e.g., exemplar-generation priming) are often impaired in AD (Monti et al., 1996; Salmon

https://doi.org/10.1017/S1355617799577084 Published online by Cambridge University Press

et al., 1988). To the extent that repetition priming memory is a manifestation of changes in the same neural system that initially processes a stimulus, the picture-naming and priming results provide convergent evidence for the existence of two neurally separable systems. One system, relatively spared in AD, may be specialized for the processing of perceptual information. Another system, damaged in AD, may be specialized for word retrieval, and damage to this system appears responsible for the naming deficit in AD.

ACKNOWLEDGMENTS

We thank Susan McNealy for assistance in assembling the experiment, Kelly Lange and Brenda Allcorn for testing patients, and Kathleen Baynes, Robert Nebes, Beth Ober and Chandan Vaidya for comments on the manuscript. This research was supported by NIH Grant AG05743 and a grant from the James S. McDonnell Foundation to the University of Pennsylvania; by NIH Grants RO1AG11121 and 5T32MH15157-18 to Stanford University; and by Alzheimer's Association Grant IIRG-92-062, NIA Grants PO1AG09466 and P30AG10161 to Rush-Presbyterian-St. Luke's Medical Center.

REFERENCES

Barker, M.G. & Lawson, J.S. (1968). Nominal aphasia in dementia. *British Journal of Psychiatry*, *114*, 1351–1356.

Bayles, K.A. & Tomoeda, C.K. (1983). Confrontation naming in dementia. *Brain and Language*, *19*, 98–114.

Devlin, J.T., Gonnerman, L.M., Andersen, E.S., & Seidenberg, M.S. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience*, *10*, 77–94.

Farah, M. & McClelland, L. (1991). A computational model of semantic memory impairment: Modality specificity and emergent category specificity. *Journal of Experimental Psychology: General*, *120*, 339–357.

Fleischman, D.A., Gabrieli, J.D.E., Reminger, S., Rinaldi, J., Morrell, F., & Wilson, R. (1995). Conceptual priming in perceptual identification for patients with Alzheimer's disease and a patient with right occipital lobectomy. *Neuropsychology*, *9*, 187–197.

Flicker, C., Ferris, S.H., Crook, T., & Bartus, R.T. (1987). Implications of memory and language dysfunction in the naming deficit of senile dementia. *Brain and Language*, *31*, 187–200.

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). "Mini-Mental State": A practical method for grading the cognitive state of outpatients for the clinician. *Journal of Psychiatric Research*, *12*, 189–198.

Gabrieli, J.D.E., Keane, M.M., Stanger, B.Z., Kjelgaard, K.S., Corkin, S., & Growdon, J.H. (1994). Dissociations among structural–perceptual, lexical–semantic, and event–fact memory systems in Alzheimer, amnesic, and normal subjects. *Cortex*, *30*, 70–103.

Gonnerman, L.M., Andersen, E.S., Devlin, J.T., Kempler, D., & Seidenberg, M.S. (1997). Double dissociation of semantic categories in Alzheimer's disease. *Brain and Language*, *57*, 254–279.

Goodglass, H., Wingfield, A., Hyde, M.R., & Theurkauf, J.C. (1986). Category-specific dissociations in naming and recognition by aphasic patients. *Cortex*, *22*, 87–102.

Hodges, J.R., Salmon, D.P., & Butters, N. (1992). Semantic memory impairment in Alzheimer's disease: Failure of access or degraded knowledge? *Neuropsychologia*, *30*, 301–314.

Huff, F.J., Corkin, S., & Growdon, J.H. (1986). Semantic impairment and anomia in Alzheimer's disease. *Brain and Language*, *28*, 235–249.

Huff, F.J., Mack, L., Mahlman, J., & Greenberg, S. (1988). A comparison of lexical–semantic impairments in left hemisphere stroke and Alzheimer's disease. *Brain and Language*, *34*, 262–278.

Humphreys, G.W., Riddoch, M.J., & Quinlan, P.T. (1988). Cascade processes in picture identification. *Cognitive Neuropsychology*, *5*, 67–103.

Keane, M.M., Gabrieli, J.D.E., Fennema, A.C., Growdon, J.H., & Corkin, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's disease. *Behavioral Neuroscience*, *105*, 326–342.

Keane, M.M., Gabrieli, J.D.E., Growdon, J.H., & Corkin, S. (1994). Priming in perceptual identification of pseudowords is normal in Alzheimer's disease. *Neuropsychologia*, *32*, 343–356.

Kirshner, H.S., Webb, W.G., & Kelly, M.P. (1984). The naming disorder of dementia. *Neuropsychologia*, *22*, 23–30.

Kuccera, J. & Francis, W.N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Martin, A. & Fedio, P. (1983). Word production and comprehension in Alzheimer's disease. *Brain and Language*, *19*, 323–341.

Martin, A., Haxby, J.V., Lalonde, F.M., Wiggs, C.L., & Ungerleider, L.G. (1995). Discrete cortical regions associated with knowledge of color and knowledge of action. *Science*, *270*, 102–105.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Proce, D., & Stadlan, E.M. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group under the auspices of Department of the Health and Human Services Task Force on Alzheimer's Disease. *Neurology*, *34*, 939–944.

Montanes, P., Goldblum, M.C., & Boller, F. (1995). The naming impairment of living and nonliving items in Alzheimer's disease. *Journal of the International Neuropsychological Society*, *1*, 39–49.

Monti, L.A., Gabrieli, J.D.E., Reminger, S.L., Rinaldi, J.A., Wilson, R.S., & Fleischman, D.A. (1996). Differential effects of aging and Alzheimer's disease upon conceptual implicit and explicit memory. *Neuropsychology*, *10*, 101–112.

Morris, J.C., Heyman, A., Mohs, R., Hughes, J.P., van Belle, G., Fillenbaum, G., Mellits, E.D., Clark, C., & the CERAD Investigators. (1989). The Consortium to Establish a Registry for Alzheimer's Disease (CERAD), I: Clinical and neuropsychological assessment for Alzheimer's disease. *Neurology*, *39*, 1159–1165.

Ober, B.A. & Shenaut, G.K. (1988). Lexical decision and priming in Alzheimer's disease. *Neuropsychologia*, *26*, 273–286.

Ober, B.A. & Shenaut, G.K. (1995). Semantic priming in Alzheimer's disease: Meta-analysis and theoretical evaluation. In P.A. Allen & T.R. Bashore (Eds.), *Age differences in word and language processing: Advances in psychology* (pp. 247–271). North Holland: Elsevier.

Oldfield, R.C. & Wingfield, A. (1965). Response latencies in naming objects. *Quarterly Journal of Experimental Psychology*, *18*, 3–16.

Park, S.M., Gabrieli, J.D.E., Reminger, S.L., Monti, L.A., Fleisch-

man, D.A., Wilson, R.S., Tinklenberg, J.R., & Yesavage, J.A. (1998). Preserved priming across study-test picture transformations in patients with Alzheimer's disease. *Neuropsychology*, *12*, 340–352.

Rochford, G. (1971). Study of naming errors in dysphasic and in demented patients. *Neuropsychologia*, *9*, 437–443.

Salmon, D.P., Shimamura, A.P., Butters, N., & Smith, S. (1988). Lexical and semantic deficits in patients with Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, *10*, 477–494.

Shuttleworth, E.C. & Huber, S.J. (1988). The naming disorder of dementia of the Alzheimer type. *Brain and Language*, *34*, 222–234.

Silveri, M.C., Daniele, A., Giustolisi, L., & Gainotti, G. (1991). Dissociation between knowledge of living and nonliving things in dementia of the Alzheimer's type. *Neurology*, *41*, 545–546.

Skelton-Robinson, M. & Jones, S. (1984). Nominal dysphasia and the severity of senile dementia. *British Journal of Psychiatry*, *145*, 168–171.

Snodgrass, J.G. & Vanderwart, M.A. (1980). Standardized set of 260 pictures: Norms for name agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *6*, 174–215.

Thompson-Schill, S.L., Aguirre, G.K., D'Esposito, M., & Farah, M.J. (1999). A neural basis for category and modality specificity of semantic knowledge. *Neuropsychologia*, *37*, 671–676.

Warrington, E. & McCarthy, R. (1983). Category-specific access dysphasia. *Brain*, *106*, 859–878.

Warrington, E. & McCarthy, R. (1987). Categories of knowledge: Further fractionation and a further integration. *Brain*, *110*, 1267–1308.

Warrington, E. & Shallice, T. (1984). Category-specific semantic impairment. *Brain*, *107*, 829–854.