Journal of the International Neuropsychological Society (2002), **8**, 83–94.
Copyright © 2002 INS. Published by Cambridge University Press. Printed in the USA.
DOI: 10.1017.S1355617701020082

What do Alzheimer's disease patients know about animals? It depends on task structure and presentation format

JILL B. RICH,[1] NORMAN W. PARK,[2] STEPHEN DOPKINS,[3] AND JASON BRANDT[4]

[1]Department of Psychology, York University and Department of Psychology, Baycrest Centre for Geriatric Care, Toronto, Ontario, Canada
[2]Kunin-Lunenfeld Applied Research Unit and Department of Psychology, Baycrest Centre for Geriatric Care, Toronto, Ontario, Canada
[3]Department of Psychology, George Washington University, Washington, DC
[4]Department of Psychiatry and Behavioral Sciences, Johns Hopkins University School of Medicine, Baltimore, MD

(RECEIVED May 18, 2000; REVISED January 16, 2001; ACCEPTED January 16, 2001)

Abstract

Deficits on tasks requiring semantic memory in Alzheimer's disease (AD) may be due to storage loss, a retrieval deficit, or both. To address this question, we administered multiple tasks involving 9 exemplars of the category "animals," presented as both words and pictures, to 12 AD patients and 12 nondemented individuals. Participants made semantic judgments by class (sorting task), similarity (triadic comparison task), and dimensional attributes (ordering task). Relative to control participants, AD patients were impaired on an unstructured sorting task, but did not differ on a constrained sorting task. On the triadic comparison task, the patients were as likely to make judgments based on size as domesticity attributes, whereas control participants made judgments based primarily on domesticity. The patients' judgments were also less consistent across tasks than those of control participants. On the ordering tasks, performance was generally comparable between groups with pictures but not words, suggesting that pictures enable AD patients to access information from semantic memory that is less accessible with lexical stimuli. These results suggest that AD patients' semantic judgments are impaired when the retrieval context is unstructured, but perform normally under supportive retrieval conditions. (*JINS*, 2002, *8*, 83–94.)

Keywords: Alzheimer's disease, Semantic memory, Format effects

INTRODUCTION

Although episodic memory impairment is the earliest and most pervasive deficit in Alzheimer's disease (AD), language abilities are frequently impaired as well. Studies of verbal memory are inextricably tied to language function; indeed, the relation between memory and language is explicitly recognized in the concept of semantic memory, as originally formulated by Tulving (1972). Semantic memory refers to a system for storing, organizing, and manipulating information pertaining to the meaning of words, concepts, and their associations, as well as to more general world knowledge. This organized knowledge system, often conceptualized as a broadly distributed network, enables people to make judgments about the properties and functions of items, such as whether a hammer is a living or nonliving thing, can be categorized as a tool, has a handle, or is larger than a screwdriver.

The two best-documented language deficits in AD occur on tasks requiring semantic memory, namely confrontation naming and verbal fluency (e.g., Bayles & Kaszniak, 1987; Bayles & Tomoeda, 1983; Huff et al., 1986; Martin & Fedio, 1983; Salmon et al., 1999). However, there is some dispute regarding the source of the impairment on these tasks. A number of investigators attribute these deficits to degraded conceptual knowledge associated with damage to brain areas critical to semantic memory (e.g., Chertkow & Bub, 1990; Hodges et al., 1992; Martin, 1992). Others argue that the impaired performance reflects a loss of lexical access to preserved concepts, possibly due to inefficient search strategies (e.g., Nebes, 1989, 1992; Ober & Shenaut, 1995). These theoretical positions may be characterized as

Reprint requests to: Jill B. Rich, Ph.D., Department of Psychology, York University, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada. E-mail: jbr@yorku.ca

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

impaired structure of semantic memory *versus* impaired access to an intact structure, respectively. Support for the former position comes from the finding that AD patients are deficient in recognizing object names (Huff et al., 1986), which indicates that deficits in lexical retrieval alone cannot account for confrontation naming deficits.

Additional evidence in support of the impaired semantic structure position comes from verbal generation (i.e., fluency) tasks. Relative to age-matched, nondemented individuals, AD patients tend to generate fewer exemplars on category fluency tasks, and their productions are less highly related (Abeysinghe et al., 1990; Eustache et al., 1990; Martin & Fedio, 1983). Moreover, although both phonemic and semantic category fluency impairments are observed in AD, semantic fluency is disproportionately impaired relative to nondemented control participants, and it declines at a faster rate than does phonemic fluency (Salmon et al., 1999, but cf. Barr & Brandt, 1996). Because retrieval inefficiencies should presumably produce equivalent deficits on the two fluency tasks, the disproportionate impairment of word generation from semantic as opposed to phonemic cues in AD has been attributed to impaired organization of semantic memory. In contrast, patients with Huntington's disease (HD), a neurodegenerative syndrome that disrupts frontal–subcortical circuits and produces a dementia characterized by prominent retrieval deficits (Brandt & Butters, 1996; Brandt & Rich, 1995), are equally impaired on phonemic and semantic word generation tasks (Monsch et al., 1994; Tröster et al., 1989).

To study the structure of semantic memory in dementia, Chan and colleagues applied clustering and multidimensional scaling (MDS) techniques to fluency task data obtained from AD patients, HD patients, and age-matched nondemented individuals (Chan et al., 1993a). Using the proximity of animal names in patients' fluency productions as an estimate of associative strength, they derived cognitive maps to represent semantic networks for each of the three groups. The maps of both the HD patients and the nondemented participants suggested that the words they generated were organized primarily along the dimension of domesticity and secondarily on the basis of size. The AD patients' maps, in contrast, revealed a poorly organized semantic network. Given the normal maps of the HD patients despite their well-documented retrieval difficulties, the maps of the AD patients were interpreted as demonstrating a breakdown in the structure of semantic knowledge rather than deficient retrieval.

Analyses based on generated exemplars are limited, however, because of sparse overall productivity on fluency tasks in AD. To circumvent this confound, Chan and colleagues applied MDS techniques to similarity data from a triadic comparison task (Chan et al., 1993b, 1995a). This paradigm requires semantic knowledge but not speaking, which avoids the problem of word retrieval. For all possible combinations of 12 animal names presented three at a time ($n = 220$ triads), participants indicated which two of the three were most alike. The resultant "cognitive maps" of AD patients indicated that they were less consistent in their use of attributes to categorize stimuli than were HD or amnesic patients or normal control participants. In addition, AD patients tended to focus on perceptual attributes, whereas all other groups tended to base their decisions on more abstract, conceptual information (domesticity). These findings were interpreted as additional evidence that the structure of semantic knowledge is impaired in AD. Subsequently, Chan et al. (1997) found that performance on the triadic comparison task deteriorates in AD as the disease progresses. Specifically, the greater the dementia severity, the less the patients focused on abstract attributes when making similarity judgments. The degree of semantic network abnormality also predicted the rate of cognitive decline in a 1-year longitudinal analysis of patients with probable AD (Chan et al., 1995b).

The greater reliance on perceptual than abstract conceptual information may be attributable to the distribution of neuropathology in AD, which affects temporal–parietal heteromodal association areas more than visual association cortex. Some investigators postulate that perceptual and lexical semantic memory systems are mediated by different brain regions (Warrington & Shallice, 1984), with pictures having preferential access to nonverbal memory and words to verbal memory. This view conceptualizes semantic memory as a multimodal system that can be fractionated (McCarthy & Warrington, 1990) and is supported by case studies of patients who provide detailed semantic information about a specific item (e.g., *rhinoceros*) when presented as a picture but are unable to access information about the item when presented as a spoken word (Lauro-Grotto et al., 1997; McCarthy & Warrington, 1988). Similarly, Chertkow et al. (1992) found that AD patients made more accurate semantic judgments with picture stimuli than with words. Moreover, PET studies with normal participants show material-specific patterns of brain activation for words and pictures (Menard et al., 1996; Perani et al., 1999).

Two recent studies that used different tasks but similar materials to those of Chan and colleagues have cast doubt upon the degraded semantic memory hypothesis of AD (Bonilla & Johnson, 1995; Ober & Shenaut, 1999). In one condition of the Bonilla and Johnson study, the same animal names used by Chan et al. (1993a) were typed onto cards. Participants were instructed to arrange the cards on a sheet of paper with similar items placed close together and dissimilar items placed further apart. In the other study (Ober & Shenaut, 1999), AD patients and control participants were instructed to arrange a set of 12 flags, each displaying the name of an animal, so that similar animals were positioned closer together than dissimilar animals. Scaling analyses in both studies showed that mildly demented AD patients' semantic judgments were unimpaired relative to control participants.

It is difficult to reconcile the findings from the studies reported above, in which normal cognitive maps were derived from AD patients, given the abnormal maps observed in the Chan studies. Perhaps AD patients' impaired perfor-

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

mance on triadic comparison and verbal fluency tasks is due to difficulties in retrieving semantic knowledge rather than to a degraded semantic network *per se*. This conclusion must be regarded as tentative, however, because HD patients show a different pattern of performance and because comparisons are being made across experiments. Nevertheless, this explanation is compatible with findings from other studies showing variations in semantic judgment performance as a function of variations in task. For example, Bayles and colleagues (Bayles et al., 1991) found that AD patients made inconsistent errors across multiple tasks involving the same stimuli. The specific pattern of errors observed suggested that performance deteriorated as a function of task difficulty rather than a loss of semantic knowledge about specific concepts. Similarly, Ober and Shenaut (1995) found that AD patients were unimpaired on semantic priming tasks that can be performed automatically, but were impaired on tasks requiring controlled or strategic processing.

As can be gleaned from the above review, the issue of the integrity of semantic memory in AD remains unresolved. The present study was designed to assess multiple judgments regarding the relatedness of items drawn from one semantic category (animals) with multiple tasks—including sorting, triadic comparison, and ordering—containing exemplars depicted in two different formats (pictures and words) among AD patients and nondemented elderly participants. We administered two versions of the sorting task, in which participants were instructed to sort cards (names or pictures of animals) into piles of things that go together. The number of piles was either specified (fixed sort condition) or unrestricted (free sort condition). In the triadic comparison task, participants indicated which two of three items were most alike for all possible triads of nine animals. The ordering task required participants to rank the animals by size (from small to large) or domesticity (tame to wild).

If AD disrupts semantic knowledge in a general and pervasive fashion, then patients should show consistent deficits across tasks. Alternatively, if semantic knowledge is relatively intact in AD, but the ability to successfully retrieve and use this information depends on the specific retrieval context, then performance should vary across tasks. Based on this line of reasoning, we hypothesized that the patients' performance on tasks in which the retrieval context is constrained and explicit would be relatively unimpaired. In contrast, deficits should emerge and widen on tasks requiring strategic or controlled processing, such as those in which the retrieval context is less structured. Thus, the AD patients should perform normally in the fixed sort compared to the free sort condition because of the greater constraints imposed by the instructions in the former task. Similarly, group differences should be minimal on the ordering task and relatively large on the triadic comparison task, because the attributes for judging stimuli are specified in the ordering tasks by the labeled continuum endpoints, whereas the basis for making similarity judgments is left to the discretion of the participant in the triadic comparison task.

Format differences may also contribute to performance differences between groups. Based on the assumption that perceptual knowledge is relatively preserved in AD and that pictures mediate access to semantic knowledge about perceptual attributes of items to a greater extent than do words, group differences should be reduced, and possibly eliminated, in the picture format condition of the size ordering task (i.e., ranking animals from small to big). Conversely, the largest group difference should emerge in the picture format condition of the triadic comparison task, because the patients are expected to give even more weight to perceptual (size) aspects of the stimuli than they typically do with lexical materials (see Chan et al., 1993b, 1995a); nondemented control participants, in contrast, should be able to access conceptual knowledge about the relations between animals even with pictorial stimuli.

METHODS

Research Participants

Twelve patients with probable AD and 12 nondemented individuals (NC) participated in all task conditions. The patients each met diagnostic criteria for probable AD as set forth by the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association (McKhann et al., 1984). Patients were recruited from either the Alzheimer's Disease Research Center (ADRC) or the Neuropsychiatry and Memory Group Clinic at Johns Hopkins. The NC participants were community-dwelling individuals recruited by advertisements posted in and around George Washington University. All NC participants rated their general health as being at least 8 on a scale of 1 (*poor health*) to 10 (*excellent health*), with a group average of 8.5 ($SD = .66$), and none had a history of neurologic or psychiatric disease.

Demographic characteristics of the patient and control participants are provided in Table 1. The groups did not differ significantly in age, education, sex distribution, or racial composition (ps $> .05$). The patients were mildly to moderately demented, as determined by their scores on the Dementia Rating Scale (Mattis, 1988).

Materials

Pictorial and lexical representations of nine high-frequency animals were used across multiple tasks, including sorting, triadic comparison judgments, dimensional ordering, naming (reading), and matching. The nine animals were *bear, cat, cow, dog, donkey, fox, rabbit, sheep, and tiger*. Lexical stimuli were printed in lowercase, Arial font, 48-point, bold type; pictorial stimuli were black-and-white line drawings from the Snodgrass and Vanderwart (1980) picture set. All stimuli were displayed on white card stock (21 × 27.5 cm landscape orientation for the triadic comparison task; 7.5 × 7.5 cm cards for all other tasks). Two sets (pictures and words) of 84 stimulus cards were developed for the triadic

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

Table 1. Demographic characteristics for each group

Variable	Alzheimer's disease			Normal control group		
	M	*SD*	Range	*M*	*SD*	Range
Age (years)	77.0	8.4	57–89	73.8	3.3	69–81
Education (years)	13.9	3.2	11–20	15.8	1.6	12–17
Sex (M:F)	6:6			5:7		
Race (White: Black)	11:1			10:2		
Dementia Rating Scale (max. = 144)	113.9	18.1	81–139	N/A		

comparison task, representing all possible triplicate groupings of the nine animals (e.g., "bear, cat, cow" "bear, cat, dog" . . . "rabbit, sheep, tiger"). Each card contained three items, and each item was centered on one point of an imaginary equilateral triangle. The order in which the three items were displayed on each page was randomized once and fixed across formats and participants. The presentation order of the 84 trials was randomized separately for the two formats and then fixed across participants. Nine additional pictures—bicycle, car, elephant, lion, monkey, pear, pineapple, strawberry, truck—from the Snodgrass and Vanderwart (1980) picture set were depicted on 7.5 × 7.5 cm cards for a pretest.

Procedure

Pretest

Prior to each test session, the nine pretest cards were shuffled, and participants were told to sort the cards into "piles of things that go together." Any participant who failed to sort the cards into three piles representing fruits, vehicles, and animals would have been excluded from the remainder of the study. However, all participants sorted the cards appropriately, so no one was excluded on this or any other basis.

Sorting

For the *free sort* condition, participants were given nine cards (words or pictures in counterbalanced order) and told, "Put these cards into piles of things that go together." The defining feature of that condition was that the number of piles created was at the discretion of the participant. The *fixed sort* condition followed immediately. Here, participants were given the same nine cards and told, "Put these cards into three piles of things that go together." Importantly, the number of piles was constrained in this condition, but the number of cards placed in each pile was not.

Triadic comparison task

For each version of the triadic comparison task (words and pictures), participants were presented with a three-ring binder containing 84 pages displaying the animal triplicates. On each trial, they were asked, "Which two of these three animals are most alike?" and were encouraged to point to their choices rather than saying the animal names aloud. Administration order of the two versions was counterbalanced within and across groups, separated by an intervening task involving similarity judgments of shapes. The trial sets were separated by 1-min rest breaks.

Ordering

All participants completed four ordering tasks, each of which required them to rank the nine animal stimuli along a graded dimension. There were four possible administration orders (i.e., size and domesticity rankings, each presented as words and pictures), counterbalanced within and across groups. For each task, the two labels representing the dimensional extremes (i.e., big/small or wild/tame) were placed at the ends of the table. The set of nine items was shuffled prior to each task, and participants were instructed to order the animals along the relevant dimension.

Naming

The nine cards with the animal pictures were shuffled and presented one at a time, with instructions to name each. Responses were recorded verbatim, and no feedback or cues were provided.

Reading

The nine cards with the animal names were shuffled and presented one at a time, with instructions to read each word aloud. Responses were recorded verbatim, and no feedback was provided.

Word–picture matching

For half the participants in each group, the word cards were distributed across the table, and the set of picture cards was handed to the participant with the instruction, "Put each picture below the name that it goes with." The remaining participants were instructed to place the words (i.e., names) below their corresponding pictures.

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

RESULTS

Free Sort

The dependent variable for the free sort data was the number of piles created by each participant (see Figure 1). A 2 (group; AD *vs.* normal control) × 2 (format; picture *vs.* word) mixed-model ANOVA showed significant effects of group [$F(1,22) = 5.70$, $p < .05$] and format [$F(1,22) = 6.41$, $p < .05$]. Overall, the patients created more piles than did the control participants. The Format × Group interaction was only marginally significant [$F(1,22) = 3.88$, $p = .06$], probably because of a lack of statistical power. *Post-hoc t*-tests showed that the control group created an equivalent number of piles for the two formats ($t < 1$), whereas the AD group sorted items into significantly more categories in the picture than in the word format [$t(11) = 2.35$, $p < .05$]. The marginally significant interaction resulted from a significant group difference in the picture [$t(22) = 2.78$, $p < .05$] but not the word [$t(22) = 1.90$, $p = .07$] condition.

Fixed Sort

Two dependent variables were derived for the fixed sort data, both of which compared the participants' categorizations to those identified *a priori* by the experimenters: (1) wild animals (tiger, bear, fox); (2) pets (cat, dog, rabbit); and (3) farm animals (cow, donkey, sheep). First, a *three-item* category score was calculated, in which points were awarded for each participant pile that contained all three experimenter-designated items, even if other items were included. For example, sorting the items as "bear, tiger, fox, rabbit," "cow, donkey, sheep," and "cat, dog" would earn 2 points (1 for wild animals, 1 for farm animals, and zero for pets) on this measure. Thus, the three-item score could range from zero to 3. A *two-item* category score was also derived. For this measure, a point was awarded for every pair of items from an experimenter-designated pile that was included in a participant pile. For example, the hypothetical sort listed above would earn 7 points (i.e., 1 each for bear–tiger, bear–fox, tiger–fox, cow–donkey, cow–sheep, donkey–sheep, and cat–dog). Thus, this score could range from zero to 9.

Mean scores based on the two scoring criteria are shown in the top half of Table 2 for each group as a function of format. Separate ANOVAs conducted for the two- and three-item category scores revealed no significant effects of format, group, or their interaction, all *p*s > .05. Overall, participants in both groups tended to sort items into the same piles hypothesized *a priori* by the experimenters.

Comparison of Free and Fixed Sorting Conditions

The emergence of a significant group difference in the free sort condition coupled with equivalent group performance in the fixed sort condition suggests that the structure provided by the constraints of the fixed sorting task benefits and even normalizes performance among AD patients. However, these findings may have resulted from some underlying difference in the dependent variables that were used for the two tasks (number of piles *vs.* content of piles). For example, the analysis involving number of piles in the free sort condition may have reflected nonsemantic problem solving rather than semantically based sorting. Therefore, in order to compare the two tasks more directly, we reanalyzed the data from the free sorting condition using the same categorization scores used in the fixed sorting condition. Mean scores derived from the two-item and three-item scoring criteria are shown in the bottom half of Table 2 for each group as a function of format. Separate repeated-measures ANOVAs with format and sorting condition as within-subject factors and group as the between-subject fac-

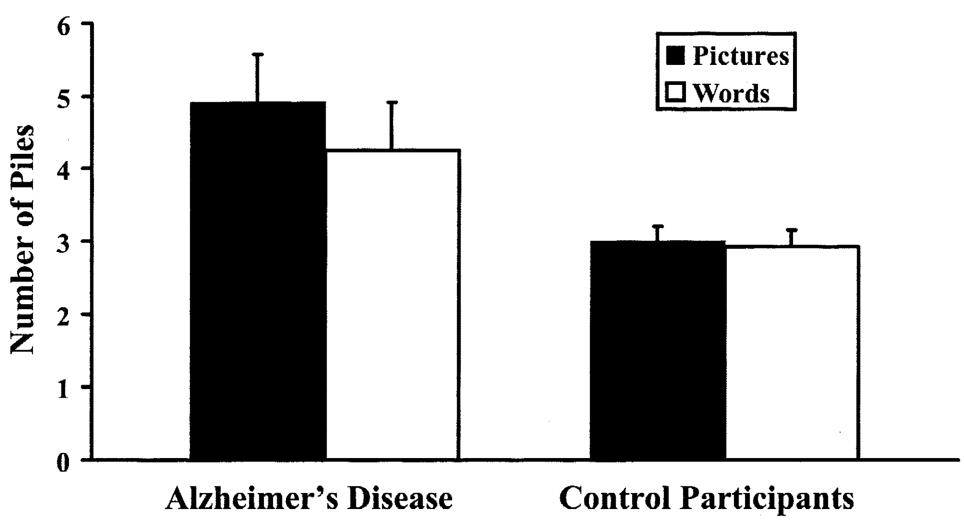

Fig. 1. Mean (+ *SEM*) number of piles generated on the free sort task as a function of format and group.

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

Table 2. Sorting performance as a function of task type, scoring criterion, format, and group

Measure	Alzheimer's disease *M*	Alzheimer's disease *SD*	Normal control *M*	Normal control *SD*
Fixed sort condition				
Three-item categories				
Picture	2.0	1.04	2.4	0.79
Word	1.7	1.07	2.2	0.87
Two-item categories				
Picture	7.0	2.09	7.3	1.87
Word	6.0	2.52	7.5	1.73
Free sort condition				
Three-item categories				
Picture	1.1	1.00	1.6	1.08
Word	1.0	1.21	1.8	0.97
Two-item categories				
Picture	4.5	3.23	5.8	2.80
Word	4.0	2.89	6.3	2.31

Note. Maximum score for the three-item categories = 3; maximum score for two-item categories = 9.

Table 3. Categorization of triadic comparison judgments as a function of format and group

Format/group	Response classification categories: Big/small	Wild/tame	Neither	Both	Tie
Words					
AD					
M	9.9	11.9	8.5	36.7	32.9
SD	6.0	6.4	7.6	15.9	2.1
NC					
M	10.2	21.0	6.9	27.1	34.7
SD	6.0	9.1	5.1	12.5	1.7
Pictures					
AD					
M	14.9	9.8	6.6	35.1	33.7
SD	9.3	7.1	3.5	11.7	2.1
NC					
M	10.1	21.2	7.7	26.4	34.5
SD	5.4	5.7	4.2	6.2	0.9

Note. The values represent percentages of responses based on 84 trials in each format.

tor were carried out for the two- and three-item categorization scores. There was a significant effect of sort type for the three-item score [$F(1,22) = 15.69$, $p < .001$], due to higher scores in the fixed than the free sort condition. Results based on the two-item score also revealed a significant effect of sort type [$F(1,22) = 11.86$, $p < .005$] in favor of the fixed sort condition, as well as a Format × Sort interaction [$F(1,22) = 10.56$, $p < .005$]. The latter reflected equivalent scores for the two formats (collapsed across group) in the free sort condition ($M = 5.15$ for both pictures and words) but higher scores with pictures ($M = 7.15$) than words ($M = 6.75$) in the fixed sort condition. No other effects were significant. Thus, AD patients create more piles than controls, but the content of those piles is semantically meaningful. Taken together, these findings suggest that the patients use narrower sorting criteria than do controls (e.g., placing semantically related items such as dog and cat together, but placing the rabbit in a separate pile which could reflect the failure to appreciate the broader semantic concept of pet as used by controls).

Similarity Judgments

We used three different approaches to analyze data from the triadic comparison task, two of which involved classification of individual responses on that task. For the classification procedure, we categorized each of the 168 similarity judgments for each participant as *big/small*, *wild/tame*, *neither*, *both*, or *tie*, as determined by that person's own ordering data (see Appendix for description of judgment classification procedure). Mean frequency counts of each type of judgment are shown in Table 3 as a function of format and group. Our first set of analyses focused on the wild/tame *versus* big/small judgments. These were investigated by performing a 2 (group) × 2 (format) × 2 (judgment: big/small *vs.* wild/tame) mixed-model ANOVA. This analysis revealed significant effects of group [$F(1,22) = 10.08$, $p < .005$], judgment [$F(1,22) = 5.40$, $p < .05$], and their interaction [$F(1,22) = 9.49$, $p = .005$]. *Post-hoc* comparisons indicated that the patients made an equivalent number of size and domesticity judgments [big/small = 12.4; wild/tame = 10.9; $t(11) < 1$], whereas the control participants were much more likely to base their judgments on domesticity than size attributes [big/small = 10.2; wild/tame = 21.1; $t(11) = 3.91$, $p < .005$]. This suggests that the patients were less likely than control participants to use the conceptual (as opposed to perceptual) features of the presented stimuli to make similarity judgments. No other effects were significant, although the three-way interaction of Group × Format × Judgment approached significance [$F(1,22) = 3.42$, $p = .078$].

A second set of analyses examined the consistency of judgments between the ordering and triadic comparison tasks. As described in the Appendix, triadic comparison trials classified as *both* referred to a subset of triads in which two of the three items had been judged closer to each other on both the size and domesticity ordering dimensions than either was to the third item. We further classified those trials as *hits* and *misses*. Specifically, when an individual chose the pair that had been ordered close together on both the big/small and wild/tame dimensions, that response was termed a *hit*. If, however, the participant chose a pair with a larger distance score, it was termed a *miss*. For example, dog and cat may have been positioned very close together on both size and domesticity dimensions. Choosing that pair as "the two items that are most alike" whenever they appeared with another item (a *hit*) would therefore reflect a degree of consistency between tasks. A hit percentage was derived by

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

dividing *hit* responses by *both* responses to correct for potential differences in opportunities to make a hit. A 2 (group) × 2 (format) repeated-measures ANOVA performed on the hit percentage score revealed a significant group difference [$F(1,22) = 5.58$, $p < .05$], due to a higher hit rate for the NC ($M = 69.4\%$) than the AD ($M = 58.4\%$) group. The effects of format and the Group × Format interaction were not significant (Fs < 1). Furthermore, the hit rate was significantly correlated with DRS score among the patients for the word [$r(11) = .72$, $p < .05$], but not the picture format [$r(11) = .50$, $p > .1$].

A third approach to analyzing the similarity judgments involved MDS, a scaling technique that has been used by others to explore the underlying semantic space based on the triadic comparison task. However, other studies typically use 12 stimuli (e.g., Chan et al., 1993b, 1995a), whereas only nine were used in this study. A reduced stimulus set was chosen for this study because nine items taken three at a time generates 84 items, whereas 12 items taken three at a time generates 220 items. Because our study included two formats, participants had to make judgments on 168 trials overall, which was comparable to the task load associated with the administration of 220 trials in other studies. However, using nine items limits the MDS to a two-dimensional solution, because the standard guideline is that the number of stimuli minus 1 should be at least 4 times greater than or equal to the dimensionality (Kruskal & Wish, 1978). We therefore used an INDSCAL solution to examine the data limited to a two-dimensional fit, but this resulted in an unacceptably high level of stress (a measurement of error in a solution) for all analyses conducted. Specifically, stress levels for the picture and word formats, respectively, were .276 and .331 for the patients and .226 and .234 for the control participants.

Ordering

The exact sequential placement of items was recorded separately for each of the four conditions (see Figures 2 and 3 for big/small and wild/tame rankings, respectively, of the

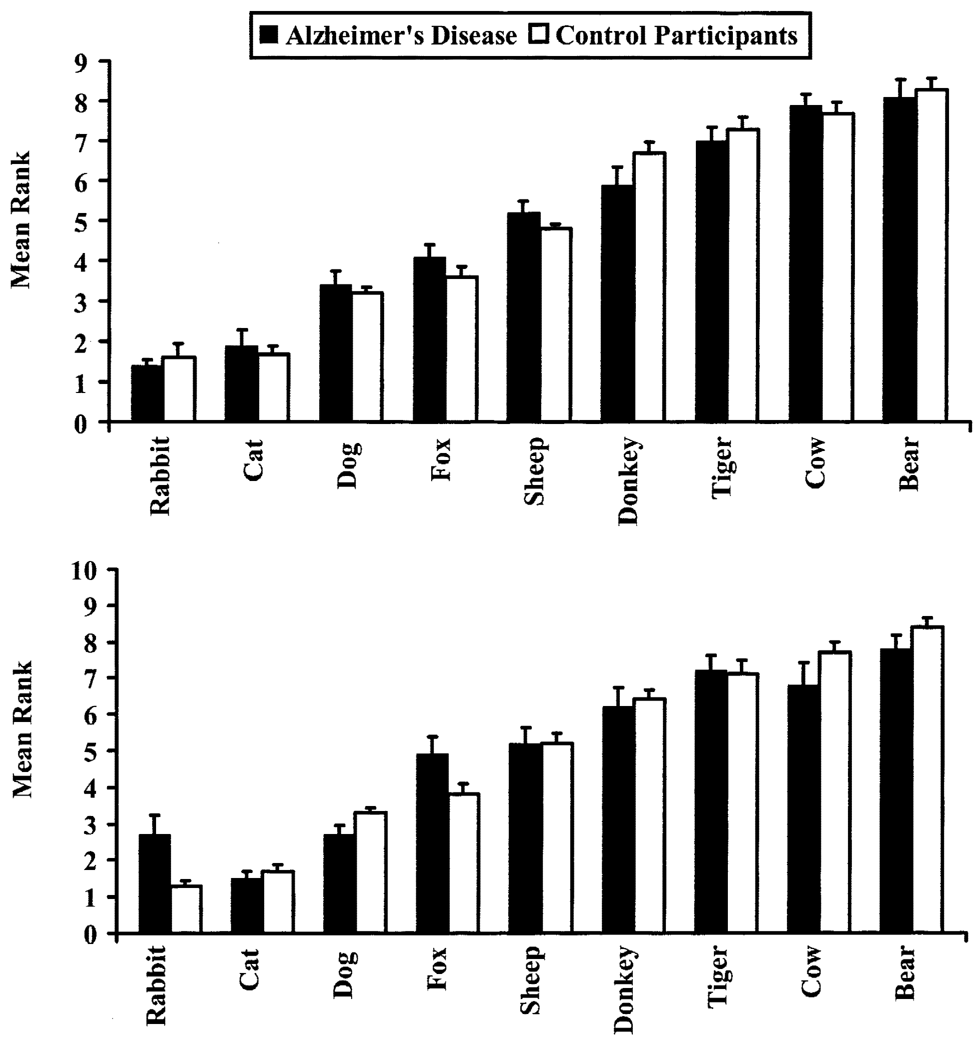

Fig. 2. Mean (+ *SEM*) size rankings of animals from small to big as a function of group and format (top panel = pictures; bottom panel = words).

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

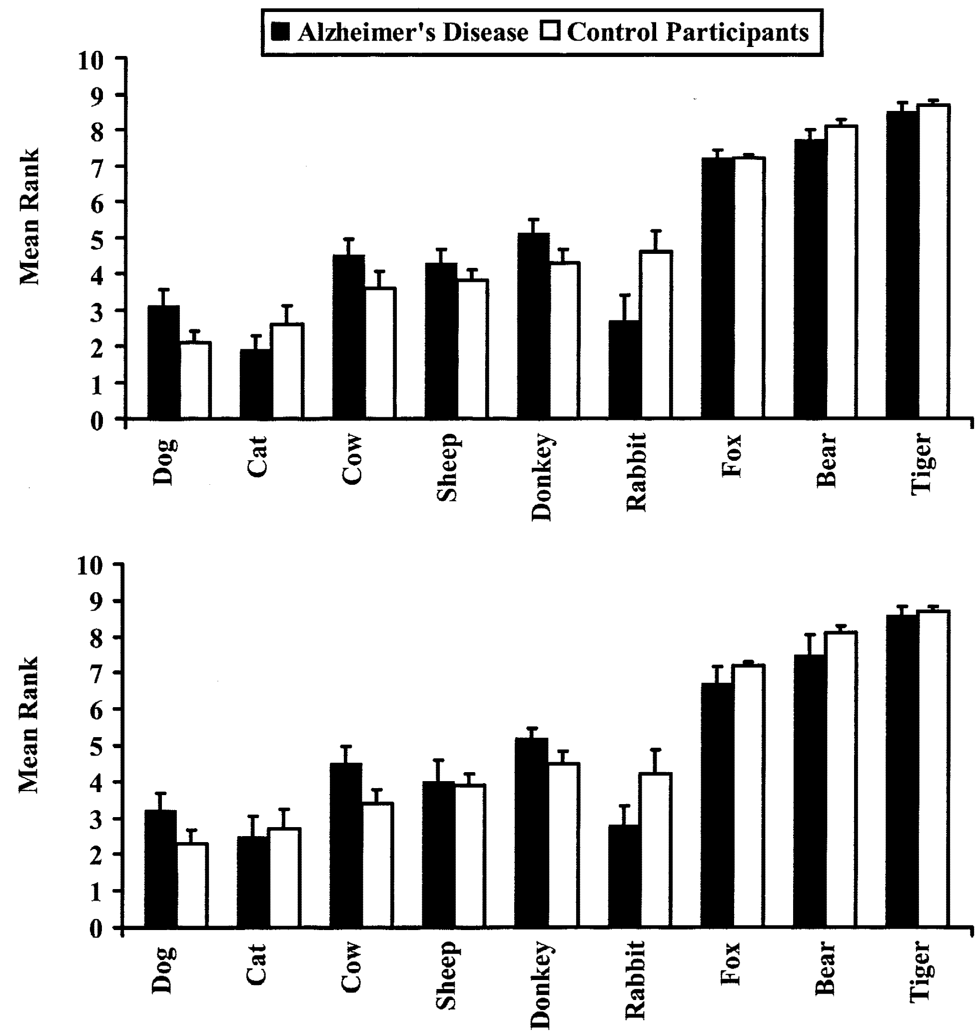

Fig. 3. Mean (+ *SEM*) domesticity rankings of animals from tame to wild as a function of group and format (top panel = pictures; bottom panel = words).

two groups for each format). Based on the mean placements of the control group, we calculated normative ordinal rankings for each item in each format/dimension condition (i.e., the item judged by the control group to be the smallest or most tame was assigned a 1, the second lowest was 2, and so on, with the item judged to be the largest or wildest assigned a 9). We then recorded the absolute value of the difference between the normative and the obtained rankings for each item in each condition on a subject-by-subject basis. Those difference scores were then summed across all nine items to create individual discrepancy scores for each condition. Because the discrepancy scores were derived from ordinal rankings, a Mann-Whitney *U* test was used to compare groups across conditions on that measure.

A Mann-Whitney *U* test performed on the big/small rankings indicated that the groups made nearly identical judgments about the relative sizes of the animals when ranking the picture stimuli (AD *M* rank = 12.46; NC *M* rank = 12.54; $U = 71.5$, $p > .1$). In contrast, the groups differed significantly in their size judgments when using the names rather than the pictures of the animals (AD *M* rank = 15.36; NC *M* rank = 9.38; $U = 34.5$, $p < .05$). To examine whether variations in the size of the line drawings influenced size rankings in the picture ordering task, we calculated a Spearman rank correlation between the size of the picture stimuli (based on the area of the minimum-sized rectangle required to enclose each drawing) and the rank order of those pictures by AD participants. Results showed that the patients' big/small rankings of the pictures were not related to the depicted size of the pictorial stimuli ($r_s = .50$, $n = 9$, n.s.).

Visual inspection of the observed wild/tame orderings displayed in Figure 3 suggests generally similar rankings between groups, although the patients appeared to rank the rabbit as considerably more tame than did the control participants. Results of a Mann-Whitney *U* test showed that the group difference in domesticity judgments approached significance in the picture format (AD *M* rank = 15.33; NC *M* rank = 9.67; $U = 38.0$, $p = .052$), and was significant in the word format (AD *M* rank = 15.54; NC *M* rank = 9.46;

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

$U = 35.5$, $p < .05$). To determine whether the differences between the two groups were attributable primarily to the rank ordering of the rabbit, this item was dropped from the analysis. A Mann-Whitney *U* test performed on the reduced data set revealed a significant group difference in domesticity judgments in the word ($U = 37.0$, $p < .05$) but not the picture ($U = 45.5$, $p > .1$) format.

Naming, Reading, and Matching

On the visual confrontation naming task, the AD group ($M = 7.9$, $SD = 1.08$) performed significantly worse than the NC group, who performed this task errorlessly [$t(22) = 3.46$, $p < .01$]. Anecdotally, this deficit appeared to be due primarily to misnaming the fox, which many patients identified as a wolf. Despite their relative difficulty in naming the line drawings of the animals, the patients were able to read the names of the items without error, and also performed flawlessly on the picture–word matching task, as did the control participants.

DISCUSSION

The primary goals of this study were to determine whether semantic judgments would vary with task demands and with different materials (words and pictures) among AD patients. We had hypothesized that the patients would be largely unimpaired relative to control participants on semantic judgments when the retrieval context was relatively constrained and explicit, but impaired when the retrieval context was more open-ended, thereby requiring controlled or strategic processing. Specific predictions arising from this hypothesis were that impaired performance among the AD group relative to the control participants would be most apparent in the free sorting and similarity judgment tasks, but group differences would be reduced or eliminated on the fixed sorting and ordering tasks. We also predicted group by format interaction effects, in which differences between pictures and words would have more of an influence on patients than control participants. Similarly, we expected that using picture stimuli would improve performance among AD patients on tasks in which perceptual processing contributes to performance (such as ordering) and would not facilitate performance on tasks in which perceptual processing detracts from performance (such as similarity judgments). Overall, results supported our general hypothesis and conformed to most of our specific predictions.

Perhaps the strongest evidence for performance differences between constrained and unstructured retrieval contexts comes from the free *versus* fixed sort tasks. AD patients were as likely to sort items into the experimenter-designated categories as their age-matched control participants in the fixed sort condition, whereas they sorted items into significantly more categories than did control participants in the more open-ended free sort condition. These two tasks are identical except that the fixed sort condition requires participants to sort items into exactly three piles, whereas in the free sort condition participants determine the number of categories themselves. Thus, as predicted, performance was normal in the constrained retrieval context and impaired in the unconstrained context. It should be noted that the groups did not differ on the free sorting task when the dependent measure was the same as that used for the fixed sorting task (i.e., the two- and three-item category scores). The significant group difference in number of piles created in the free sort condition, coupled with equivalent group performance in categorization scores for the same task, together suggest that the content of the piles created by the patients was semantically meaningful, yet their groupings were not as semantically broad as those created by the controls.

Also as predicted, AD patients were impaired on the relatively unstructured triadic comparison task. Specifically, the patients were as likely to make judgments based on size as domesticity, whereas normal control participants were more likely to base their judgments on domesticity. These findings are similar to those of Chan and colleagues (Chan et al., 1993b, 1995a) who also showed that control participants were more likely than AD patients to judge items on the basis of domesticity. Based on those findings, the authors argued for a loss of conceptual knowledge in AD. In fact, it was because of Chan's reports indicating that size and domesticity were the two primary dimensions underlying decisions in the triadic comparison task that we chose to use those two dimensions in our ordering tasks. However, our data show that AD patients make the same relative judgments about the domesticity attributes of animals as do control participants when explicitly instructed to order items on a wild/tame dimension, at least when those rankings are based on pictures of animals. This finding suggests that domesticity information is represented in semantic memory and that, under certain conditions, AD patients are able to access such information. Thus, the impaired performance of AD patients on the triadic comparison task may be due to the unstructured nature of the task (i.e., no guidance regarding the basis on which items should be judged as "most alike") rather than to degradation of domesticity information. On the other hand, our results could be considered consistent with a soft form of the degradation hypothesis, in which "degradation" refers to a diminished semantic concept in the sense of being "frayed at the edges" rather than to a complete loss of semantic knowledge.

An additional finding from the triadic comparison task is that AD patients were less consistent in their judgments than were control participants. That is, nondemented participants were more likely to select a pair of items as being most alike on the triadic comparison task if those items were judged by a given participant to be closer to each other on the ordering tasks than either was to the third item. The lower consistency of AD patients on this task accords with findings showing that AD patients tend to have more variable associative links between concepts than do control participants when triadic comparison data are analyzed using scaling procedures (Chan et al., 1993b, 1997). We propose that the inconsistency between tasks observed among our

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

AD patients is due to the different degree of support provided in the two tasks (ordering *vs*. triadic comparison) rather than to a structural alteration of the semantic network in AD (e.g., Chan et al., 1995a). We would expect performance to be much more consistent across two tasks with constrained retrieval conditions.

Another factor that varies across tasks and may account for differences between studies is intragroup variance, which influences the ability to detect between-group differences. For example, both Ober and Shenaut (1999) and Bonilla and Johnson (1995) required participants to position animal names in two-dimensional space, with similar animals placed close together and dissimilar animals further apart. AD patients did not differ from control participants in either of these studies. Protocol analyses in the former study indicated that positioning decisions were based on multiple criteria (e.g., cat family, wild animals, ungulates, herbivores, etc.) both within and across participants. Such shifting, local criteria are associated with a large degree of error variance. In contrast, the ordering task used in the present study required participants to rank animals along a single dimension, which likely reduced error variance and increased the ability to detect differences between the patients and controls.

A second purpose of this study was to investigate potential effects of format on semantic judgments in AD. As predicted, format effects were more pronounced in the patients than in the control participants, and this was most apparent on the ordering tasks. In both the big/small and wild/tame ordering conditions, the patients' relative rankings of the animals differed from those of the control participants in the word format conditions. Importantly, the provision of pictorial stimuli enhanced performance among the AD patients in both conditions: Patients and control participants were indistinguishable in their rank orderings of the animal pictures on the big/small dimension, and they differed only marginally on the wild/tame dimension. That marginal difference was apparently due to different judgments about a single picture (i.e., the rabbit, which was judged to be more wild than farm animals by the control participants and less wild than farm animals by the patients). The groups displayed equivalent relative judgments about the domesticity of all other animal pictures, as indicated by analyses conducted with the rabbit deleted.

Given the pattern of intact size rankings with pictures and impaired size rankings with words among the patients, one might be tempted to conclude that the pictures provide direct, relevant information about size that is not provided by words and that that information guides the patients' judgments. However, the normal performance observed in the picture condition does not appear to be based on an analysis of the visible characteristics of the stimuli, because the size of the pictorial stimuli and the actual size of the animals were not correlated. Similarly, domesticity judgments cannot be made by analyzing a line drawing. Instead, both judgments appear to require retrieval of information from semantic memory, and the finding of differences in performance between pictures and words suggests that different information is accessed from semantic memory by the two presentation formats.

Our findings of format differences are consistent with results of a study by Chertkow et al. (1992) involving AD patients selected specifically because they showed a semantic memory deficit but normal visual perceptual processing. In one experimental condition, AD patients and normal control participants were presented pictures and words of concrete objects. As each item (e.g., "saw") was presented, participants answered a perceptual question (e.g., "Is the edge made of metal or wood?") or a functional question (e.g., "Do you cut things with it or lift with it?") about the item. In that study, AD patients performed better with pictures than with words on both types of questions. Our format effects are also consistent with the multimodal semantic memory hypothesis (Lauro-Grotto et al., 1997; McCarthy & Warrington, 1988; Shallice, 1988), which postulates that semantic knowledge is organized into different sensory modalities that reflect the origin or form of stored information (e.g., visual or verbal). Other investigators have proposed that there is an amodal, single semantic system that can be accessed by words, pictures, or other meaningful stimuli (Caramazza et al., 1990; Riddoch et al., 1988). According to Caramazza et al. (1990), the perceptual description of a picture as a whole provides access to its semantic representation; in addition, the perceptual features associated with the picture serve as further cues to stored features of the object. In contrast, a word provides access only to its semantic representation. This model accommodates the finding of better perceptual judgment (e.g., size ordering) performance with pictures than words; however, it is not clear how it could account for better nonperceptual judgments (e.g., domesticity condition) with pictures. Such findings are better explained by the multimodal semantic memory model (though see Hillis et al., 1995).

In summary, findings from this and several other studies show that AD patients are impaired when the retrieval context is relatively undefined or unconstrained, but perform normally when it is structured or constrained. In addition, AD patients tend to perform differently when presented pictures of animals compared to words. The former finding is compatible with the more general notion of environmental support proposed by Craik and colleagues (e.g., Craik et al., 1987). That theory was developed to describe performance improvements observed among healthy elderly individuals with clearly defined as opposed to unstructured retrieval contexts. The present results also fit nicely with the distinction between strategic or controlled and automatic memory processes (e.g., Jacoby, 1991; Moscovitch, 1992). According to this perspective, AD patients in this study show relatively intact semantic memory, as demonstrated in the constrained task conditions. They have difficulty, however, when a less well-defined retrieval context requires them to engage in constructive or strategic processes before responding (for a similar view, see also Bonilla & Johnson, 1995; Johnson et al., 1995). This interpretation also fits with findings from semantic priming stud-

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

ies. A meta-analysis of these studies indicated that AD patients show generally preserved semantic priming on tasks that can be performed relatively automatically, but they perform abnormally on tasks that encourage strategic processing, such as those with long interstimulus intervals (Ober & Shenaut, 1995).

The results of this study may have important implications for patient treatment and management. Coupled with findings from other studies (for a review, see Park & Ingles, 2001), the present results suggest that the provision of environmental support, which reduces demands on controlled processing, benefits performance in AD and reveals conceptual knowledge that is not apparent in less structured retrieval conditions. In addition, the provision of pictorial cues appears to enable AD patients to gain access to certain types of semantic knowledge that are inaccessible on the basis of lexical retrieval cues. Although further basic and applied research is required, these results suggest that appropriate structuring of the external environment and the use of pictorial stimuli may improve performance by AD patients on tasks mediated by semantic memory.

ACKNOWLEDGMENTS

This study was supported in part by grants from the National Institute on Aging (AG00149 and AG05146) to J.B. The first author was also supported by the John Boogher Fellowship in Memory Disorders at Johns Hopkins University School of Medicine. We thank Ron Collis for assistance in data analysis and Malcolm Binns for statistical advice.

REFERENCES

Abeysinghe, S.C., Bayles, K.A., & Trosset, M.W. (1990). Semantic memory deterioration in Alzheimer's subjects: Evidence from word association, definition, and associate ranking tasks. *Journal of Speech and Hearing Research*, *33*, 574–582.

Barr, A. & Brandt, J. (1996). Word-list generation deficits in dementia. *Journal of Clinical and Experimental Neuropsychology*, *18*, 810–822.

Bayles, K.A. & Kaszniak, A.W. (1987). *Communication and cognition in normal aging and dementia*. Boston: College-Hill Press.

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

Bayles, K.A., Tomoeda, C.K., Kaszniak, A.W., & Trosset, M.W. (1991). Alzheimer's disease effects on semantic memory: Loss of structure or impaired processing? *Journal of Cognitive Neuroscience*, *3*, 166–182.

Bonilla, J.L. & Johnson, M.K. (1995). Semantic space in Alzheimer's disease patients. *Neuropsychology*, *9*, 345–353.

Brandt, J. & Butters, N. (1996). Neuropsychological characteristics of Huntington's disease. In I. Grant & K.M. Adams (Eds.), *Neuropsychological assessment of neuropsychiatric disorders* (2nd ed., pp. 312–341). New York: Oxford University Press.

Brandt, J. & Rich, J.B. (1995). Memory disorders in the dementias. In A.D. Baddeley, B.A. Wilson, & F.N. Watts (Eds.), *Handbook of memory disorders* (pp. 243–270). Chichester, UK: Wiley.

Caramazza, A., Hillis, A.E., Rapp, B., & Romani, C. (1990). The multiple semantics hypothesis: Multiple confusions? *Cognitive Neuropsychology*, *8*, 161–190.

Chan, A.S., Butters, N., Paulsen, J.S., Salmon, D.P., Swenson, M.R., & Maloney, L.T. (1993a). An assessment of the semantic network in patients with Alzheimer's disease. *Journal of Cognitive Neuroscience*, *5*, 254–261.

Chan, A.S., Butters, N., & Salmon, D.P. (1997). The deterioration of semantic networks in patients with Alzheimer's disease: A cross-sectional study, *Neuropsychologia*, *35*, 241–248.

Chan, A.S., Butters, N., Salmon, D.P., Johnson, S.A., Paulsen, J.S., & Swenson, M.R. (1995a). Comparison of the semantic networks in patients with dementia and amnesia. *Neuropsychology*, *9*, 177–186.

Chan, A.S., Butters, N., Salmon, D.P., & McGuire, K.A. (1993b). Dimensionality and clustering in the semantic network of patients with Alzheimer's disease, *Psychology and Aging*, *8*, 411–419.

Chan, A.S., Salmon, D.P., & Butters, N. (1995b). Semantic network abnormality predicts rate of cognitive decline in patients with probable Alzheimer's disease. *Journal of the International Neuropsychological Society*, *1*, 297–303.

Chertkow, H. & Bub, D. (1990). Semantic memory loss in dementia of Alzheimer's type. *Brain*, *113*, 397–417.

Chertkow, H., Bub, D., & Caplan, D. (1992). Constraining theories of semantic memory processing: Evidence from dementia. *Cognitive Neuropsychology*, *9*, 327–365.

Craik, F.I.M., Byrd, M., & Swanson, J.M. (1987). Patterns of memory loss in three elderly samples. *Psychology and Aging*, *2*, 79–86.

Eustache, F., Cox, C., Brandt, J., Lechevalier, B., & Pons, L. (1990). Word-association responses and severity of dementia in Alzheimer disease, *Psychological Reports*, *66*, 1315–1322.

Hillis, A.E., Rapp, B., & Caramazza, A. (1995). Constraining claims about theories of semantic memory: More on unitary versus multiple semantics. *Cognitive Neuropsychology*, *12*, 175–186.

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.

Jacoby, L.L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, *30*, 513–541.

Johnson, M.K., Hermann, A.M., & Bonilla, J.L. (1995). Semantic relations and Alzheimer's disease: Typicality and direction of testing. *Neuropsychology*, *9*, 529–536.

Kruskal, J. & Wish, M. (1978). *Multidimensional scaling*. Beverly Hills, CA: Sage.

Lauro-Grotto, R., Piccini, C., & Shallice, T. (1997). Modality-specific operations in semantic dementia. *Cortex*, *33*, 593–622.

Martin, A. (1992). Degraded knowledge representations in patients with Alzheimer's disease: Implications for models of semantic and repetition priming. In L.R. Squire & N. Butters (Eds.), *Neuropsychology of memory* (2nd ed., pp. 220–232). New York: Guilford Press.

Martin, A. & Fedio, P. (1983). Word production and comprehension in Alzheimer's disease: The breakdown of semantic knowledge. *Brain and Language*, *19*, 124–141.

Mattis, S. (1988). *Dementia Rating Scale*. Odessa, FL: Psychological Assessment Resources.

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press

McCarthy, R.A. & Warrington, E.K. (1988). Evidence for modality-specific meaning systems in the brain. *Nature*, *334*, 428–430.

McCarthy, R.A. & Warrington, E.K. (1990). *Cognitive neuropsychology*. New York: Academic Press.

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

Menard, M.T., Kosslyn, S.M., Thompson, W.L., & Alpert, N.M. (1996). Encoding words and pictures: A positron emission tomography study. *Neuropsychologia*, *34*, 185–194.

Monsch, A.U., Bondi, M.W., Paulsen, J.S., Brugger, P., & Butters, N. (1994). A comparison of category and letter fluency in Alzheimer's disease and Huntington's disease. *Neuropsychology*, *8*, 25–30.

Moscovitch, M. (1992). Memory and working-with-memory: A component process model based on modules and central systems. *Journal of Cognitive Neuroscience*, *4*, 257–267.

Nebes, R.D. (1989). Semantic memory in Alzheimer's disease. *Psychological Bulletin*, *106*, 377–394.

Nebes, R.D. (1992). Semantic memory dysfunction in Alzheimer's disease: Disruption of semantic knowledge or information-processing limitation? In L.R. Squire & N. Butters (Eds.), *Neuropsychology of memory* (2nd ed., pp. 233–240). New York: Guilford Press.

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

Ober, B.A. & Shenaut, G.K. (1999). Well-organized conceptual domains in Alzheimer's disease. *Journal of the International Neuropsychological Society*, *5*, 676–684.

Park, N.W. & Ingles, J.L. (2001). Effectiveness of attention rehabilitation after an acquired brain injury: A meta-analysis. *Neuropsychology*, *15*, 199–210.

Perani, D., Schnur, T., Tettamanti, M., Gorno-Tempini, M., Cappa, S.F., & Fazio, F. (1999). Word and picture matching: A PET study of semantic category effects. *Neuropsychologia*, *37*, 293–306.

Riddoch, M.J., Humphreys, G.W., Coltheart, M., & Funnell, E. (1988). Semantic systems or system? Neuropsychological evidence re-examined. *Cognitive Neuropsychology*, *5*, 3–25.

Salmon, D.P., Heindel, W.C., & Lange, K.L. (1999). Differential decline in word generation from phonemic and semantic categories during the course of Alzheimer's disease: Implications for the integrity of semantic memory. *Journal of the International Neuropsychological Society*, *5*, 692–703.

Shallice, T. (1988). *From neuropsychology to mental structure*. Cambridge, UK: Cambridge University Press.

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

Tröster, A.I., Salmon, D.P., McCullough, D., & Butters, N. (1989). A comparison of category fluency deficits associated with Alzheimer's and Huntington's disease. *Brain and Language*, *37*, 500–513.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381–403). New York: Academic Press.

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

APPENDIX

SCORING PROCEDURE FOR TRIADIC COMPARISON RESPONSES

As a first step in classifying similarity judgments, each triplicate from the two triadic comparison tasks was broken down into its three constituent pairs. Distance scores were then assigned to each pair on the basis of the relative rankings of the pair items on the ordering tasks. For example, the triplicate "bear, cat, cow" comprises the pairs *bear–cat*, *bear–cow*, and *cat–cow*. The distance scores for each of those pairs would be different for each participant, depending on individual order rankings (and could also differ within-subject for the two formats). Hypothetically, someone may have ranked the cards in the following sequences for one format of the ordering task: *wild/tame = dog, cat, cow, sheep, donkey, rabbit, fox, bear, tiger; big/small = rabbit, cat, dog, fox, sheep, tiger, donkey, bear, cow*.

For the wild/tame dimension, this person's distance scores for the "bear, cat, cow" triplicate would therefore be: bear–cat = 6, bear–cow = 5, and cat–cow = 1; for the big/small dimension, the distances would be: bear–cat = 6, bear–cow = 1, and cat–cow = 7. Based on these distances, a response of "cat–cow" by this person on this triadic comparison trial would be categorized as a *wild/tame* judgment, "bear–cow" would be categorized as *big/small*, and "bear–cat" would be *neither*.

When the closest distance for both ordering dimensions corresponded to the same pair of items from the triadic comparison task, that pair would be categorized as a "both" response. For example, using the same rank orders listed above and the triplicate "sheep, donkey, cat," the pair "sheep–donkey" is ranked closer on both the big/small (distance = 2) and wild/tame (distance = 1) dimensions relative to the other two pairs (sheep–cat and donkey–cat). The response of sheep and donkey as being most alike on that triadic comparison trial would therefore be categorized as *both* a big/small and wild/tame judgment. Finally, when two-item pairs in a given trial were ranked equidistant within a dimension, that trial would be categorized as a *tie* if the distance of the two pairs were smaller than the distance of the remaining pair. For example, using the hypothetical rank orders above and the triplicate "cow, dog, donkey," the pairs cow–dog and cow–donkey each have a distance score of 2 on the wild/tame dimension, which is smaller than the dog–donkey pair (distance = 4).

https://doi.org/10.1017/S1355617701020082 Published online by Cambridge University Press