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Semantic Space in Alzheimer's Disease Patients

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A within-category sorting task was used to investigate conceptual relations from 2 semantic categories (animals and occupations) in mild and moderately impaired Alzheimer's disease (AD) patients. A multidimensional scaling analysis was applied to the data. The resulting 2-dimensional solutions indicated that mildly affected AD patients sorted within-category terms in a manner largely consistent with controls' performance but were less consistent in their application of domain knowledge. Moderate AD patients' solutions were less similar to controls' solutions. Mild AD patients' explanations of their sorting schemes were similar to those given by controls but less focused. Together these findings suggest that attribute knowledge may remain largely accessible in mild AD; however a deficiency in recruiting reflective processes in the service of task-related goals may limit the selective application of this information.

Many recent psychological investigations of Alzheimer's disease (AD) have been concerned with understanding the gradual but dramatic disruption of semantic memory as the disease progresses (Nebes, 1989). The term *semantic memory* refers to an organized body of general knowledge and beliefs one has about the world (Tulving, 1972). Conceptual knowledge (e.g., knowing that a bird is a kind of animal), as well as knowledge about how objects are related to each other within any given conceptual field, are important aspects of semantic knowledge. Knowledge of the parts, properties, and functions of an object (i.e., *attribute knowledge*) may be particularly important for recognizing the semantic relations among any group of objects.

Within-category fluency tasks have been used to explore the structure of semantic and attribute knowledge in AD (Butters, Granholm, Salmon, Grant, & Wolfe, 1987; Martin & Fedio, 1983; Ober, Dronkers, Koss, Delis, & Friedland, 1986; Weingartner et al., 1981). For example, Weingartner, Kawas, Rawlings, and Shapiro (1993) observed that AD patients generate fewer members of categories (fruits and vegetables) overall, and particularly fewer members of low and moderate dominance as compared with matched controls. Chan, Butters, Paulsen, et al. (1993) used the verbal fluency task to investigate the structure of semantic knowledge for animals. However, they took a different approach than the studies mentioned above in that clustering analyses and multidimensional scaling (MDS) techniques were applied to the obtained fluency data. In their study, AD patients, Huntington's disease (HD) patients, and age-matched controls were asked to name as many animals as they could within 60 s. The guiding assumption was that subjects' naming responses would correspond to the automatic spreading activation occurring within the semantic network. Thus, counting the *interanimal distance* (the degree of separation between any two given animals) would yield a measure of the semantic distance between any two items. These distances could then be treated as similarity data and subjected to clustering and MDS analyses. HD patients were included in order to investigate whether AD patients' semantic deficits are the result of a generalized retrieval deficit (known to be a feature of HD) or whether there is an actual disruption in the organization and structure of semantic knowledge. The MDS analysis yielded a cognitive map for each group, and ADDTREE clustering analysis (Sattath & Tversky, 1977) was used to group items within the map.

The maps of the normal control group and the HD group were very similar; each group appeared to organize animal terms along the dimension of domesticity. In contrast, AD patients' generation of animal terms yielded a cognitive map that was not clearly interpretable. AD patients appeared to make imperfect use of the domesticity dimension in addition to the dimension of size and possibly other indefinite dimensions. Chan, Butters, Paulsen, et al. (1993) argued that because the map obtained from HD patients, who are known to suffer from output deficiencies, yielded a structure that was consonant with that derived from controls' output, the AD patients' uninterpretable groupings of animal terms must reflect a disruption in the semantic network itself. However, generative fluency tasks have been shown to be particularly difficult for AD patients (Bayles, Tomoeda, Kaszniak, & Trosset, 1991) perhaps because of an impairment in engaging a directed retrieval strategy (Hartman, 1991). AD patients may be unable to make appropriate use of the hierarchical structure of semantic memory to guide their retrieval in this task and thereby may also suffer from a type of retrieval deficit, albeit of a different form than the retrieval deficit observed in HD

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patients (Monsch et al., 1994; Tröster, Salmon, McCullough, & Butters, 1989). Thus the alternative interpretation that AD patients' maps reflect verbal fluency deficits independent of semantic network structure is not necessarily ruled out by the inclusion of the HD group.

Chan, Butters, Salmon, and McGuire (1993) took a different approach. Here patients diagnosed as having probable AD and normal age- and education-matched controls were presented with a triadic comparison task. This task required participants to indicate which two of three presented animals are "most alike." Participants made similarity comparisons on every possible triadic combination of 12 animal names for a total of 220 comparison judgments. MDS techniques were then applied to the similarity data to obtain a map of the underlying semantic structure. Approximately 1 week later, the procedure was repeated, and additionally participants completed a sorting task. This task required participants to sort the 12 animal names along the specified dimensions of size, predation, and domesticity, one dimension at a time. The sorting task was included to assist in interpreting the dimensions of the MDS derived cognitive maps. Derived maps of the normal and AD group supported previous research indicating that AD patients tended to organize animal terms along the dimension of size, whereas controls chose the dimension of domesticity for their organizational scheme. However, the sorting task revealed that AD patients did not use the size dimension perfectly. When errors were made in sorting, they tended to be a result of misclassifying small and large animals. The interpretation of the MDS derived cognitive maps, suggested by the authors, emphasized the dependence AD patients appear to display on the perceptual dimension of size in contrast to controls' dependence on the more abstract dimension of domesticity.

Chan, Butters, Salmon, and McGuire (1993) further speculated that this differential application of perceptual attribute knowledge could be a function of temporal cortex pathology. Arnold, Hyman, Flory, Damasio, and Van Hoesen (1991) showed that the temporal lobes and limbic area are more severely affected by neuropathological changes associated with AD compared with the frontal, parietal, and occipital lobes. Chan, Butters, Salmon, et al., (1993) hypothesized that AD patients may rely less on abstract attribute information, presumably supported by temporal lobe structures, in deference to information (presumably perceptual) supported by less damaged visual association cortex. This may account for the deficient performance of AD patients on a variety of tasks, including sorting, association ranking, and tests of direct attribute knowledge because AD patients would make judgments using perceptual as opposed to more abstract criteria.

In short, this hypothesis suggests that the semantic memory impairments observed in AD may be a function of disintegration of semantic structure as a consequence of relatively focal neurologic damage to the temporal lobe regions. However, Chan, Butters, Salmon, et al.'s, (1993) data from the sorting task showed that AD patients make a significant number of errors relative to matched controls when making perceptual judgments, as well as more abstract judgments. This suggests that information that is more accessible (by this hypothesis, perceptual information) is not always appropriately used. Perhaps dysfunctional cognitive operations that underlie the use of visuoperceptual information, such as selective attention, contribute to such perceptual judgment errors (Nebes, 1992).

The triadic comparison task is especially dependent on the ability to actively manipulate available information for making judgments. This task required participants to make over 200 judgments between related items (which two of three items are most similar). Previous work suggests that AD patients may be particularly vulnerable to inhibition from repeated encounters with related words (Ober & Shenaut, 1988); effortful processing, such as is required for making judgments, may increase the strength of the inhibitory effect (Blaxton & Neely, 1983).

The aim of the present study was to assess knowledge of the semantic relations among a group of items within a given category by observing whether AD patients would organize related items in a way similar to normal elderly participants. We used the method of direct grouping, which simply requires that participants sort the items into as many groups as they wish without restricting the number of items that can be placed in any particular group (Miller, 1969; Rapoport & Fillenbaum, 1972). Of interest was whether AD patients' groupings would reflect recognition and appreciation of the same relations among the items that normal elderly recognize and use. If it is the case that AD disrupts attribute knowledge such that members of a category are no longer discriminable (Martin, 1992), then one might expect that AD patients would reveal their inability to distinguish between members of a category by sorting same category items into fewer groups than normal elderly.

A further purpose was to explore the possibility that AD patients show greater disruption of abstract than perceptual information by having participants complete the organization task for members of two categories (animals and occupations) that differed along perceptual–abstract dimensions. If AD patients have a particular deficit in manipulating and applying abstract knowledge, one might expect that the sorting of occupation terms, which controls typically sort along relatively abstract dimensions such as prestige or independence (Burton, 1972), would show greater disruption in the AD groups than the sorting of the animal terms. To the extent that attribute knowledge is important for making discriminations among category members, this study further investigates the ability of AD patients to strategically use this knowledge. The organization patterns observed for each group were subjected to the continuous nonmetric method of MDS (Kruskal, 1964) using group summary data. In addition, participants' verbal descriptions of their organization were recorded to aid in the interpretation of the resulting semantic space.

Method

Participants

Patients were diagnosed as having probable AD as defined 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) and had no history or signs of other psychiatric or neurological disease, including multi-infarct dementia. Patients were recruited from Princeton University area physicians and the Comprehensive Services on Aging Institute for Alzheimer's Disease and Related Disorders at the

University of Medicine and Dentistry of New Jersey. Patients taking psychotropic medications were not tested. Normal elderly controls were primarily spouses of patients.

The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was administered to all participants. The MMSE is a brief test of general cognitive functions such as orientation, short-term memory, language skills, and visuo-constructional skills. AD patients were classified as mildly affected if their MMSE score was 19 or above (30 possible); patients with a score of 18 or less were classified as moderately affected. In addition, an abbreviated form of the Similarities subscale (Albert & Moss, 1988) of the Wechsler Adult Intelligence Scale—Revised was administered to most participants (see Table 1). Similarities is a test of the ability to generate a category for two concepts. For example, subjects are asked, "In what way are a chair and a table alike?" The most appropriate response would be, "They are both furniture." The category furniture implies an abstract relation between two objects in contrast to a response such as, "They both have legs." This would be a statement about shared perceptual features. Table 1 shows the mean age, education, MMSE, and Similarities scores for the participants completing each category sorting task (not every participant completed both sorts because of time constraints).

Materials

Twelve items from each category (animals and occupations) were chosen. The specific items were as follows: Animals: bear, cat, cow, dog, elephant, giraffe, horse, lion, rabbit, sheep, tiger, zebra (from Chan, Butters, Paulsen, et al., 1993); Occupations: chemist, cook, dentist, detective, doctor, fireman, lawyer, mechanic, nurse, plumber, professor, teacher (subset of terms used in Tversky & Hutchinson, 1986). Stimuli were printed in Helvetica 24 pt bold type and mounted onto cards (2 × ¾ inch; 5.1 × 1.9 cm). Subjects arranged the cards on a 18 × 24 inch (45.8 × 60.9 cm) sheet of white paper. Placement of the cards was marked by the experimenter. Descriptions of the participants' sorting schemes were audiotaped and transcribed. Order of the two categories was counterbalanced across subjects.

Procedure

Participants were presented with a sheet of paper and 12 cards from one of two categories and instructed to "arrange these cards on this sheet of paper in a way that reflects their similarity to each other. That is, if you believe that items are similar, put them close together. If you believe that items are not similar, put them farther apart. Please use the whole sheet of paper." Participants were permitted to take as much time as needed. After indicating that they had completed the sort, the experimenter marked the placement of the cards on the sheet of paper. Finally, participants were asked to explain, "How did you go about organizing the words the way they are?" This portion was audiotaped and later transcribed for use in constructing a grouping or similarity matrix for each individual for each category, as well as in aiding in dimension interpretation. Any spontaneous comments made by participants as they were completing the sorting task were recorded as well.

Results

First, the number of groups produced by each participant was recorded (a group was identified when cards were placed together and participants indicated such). The mean number of groups formed by each group for the animal sort were controls = 4.05, SD = 1.67; mild AD = 5.11, SD = 2.37; and moderate AD = 3.67, SD = 2.34. An analysis of variance performed on these data showed that controls, mild ADs, and moderate ADs did not differ in number of groups formed, $F(2, 32) = 1.22$, $MS = 4.76$, $p < .31$. For the occupation sort, the mean number of groups formed by each group were controls = 4.84, SD = 1.89; mild AD = 5.00, SD = 1.41; moderate AD = 5.67, SD = 2.58. These means did not significantly differ from each other ($F < 1$). Thus, both mild and moderate AD patients made distinctions among items within each category. The characteristics of these distinctions were explored with multidimensional scaling.

Participants' sorts of each category were transcribed into an incidence half-matrix. Each half-matrix represented all possible combinations of terms; cell x,y represents the particular pair of category items x and y (e.g., *cat* and *cow*). Following Miller (1969), a 1 was placed in Cell x,y if that pair of terms was put together and 0 if they were in different groups. The frequency distribution of pairs of terms sorted together within

Table 1
Demographic Characteristics of Alzheimer's (AD) Patients and Controls Completing Animal and Occupation Sorts

Characteristic	Control *M*	Control *SD*	Mild AD *M*	Mild AD *SD*	Moderate AD *M*	Moderate AD *SD*
			Animal sort[a]			
Age (years)	75.0	6.6	76.0	7	74.0	6.9
Education (years)	13.3	2.4	13.0	2.6	12.8	1.1
MMSE score	28.2	1.8	23.4	3.6	13.4	2.6
Similarities score	10.5	2.9	8.7	2.1	5.0	2.5
			Occupation sort[b]			
Age (years)	75.0	6.0	77.0	5.6	72.0	6.6
Education (years)	13.3	2.3	13.0	1.7	12.8	1.1
MMSE score	28.3	1.7	23.1	2.6	13.5	3.0
Similarities score	10.5	2.9	8.7	2.1	4.7	2.4

Note. MMSE = Mini-Mental State Examination. Similarities is a subscale of the Wechsler Adult Intelligence Scale.
[a]19 controls (n = 20), 7 mild (n = 9), and 5 moderate (n = 6) AD subjects completed the Similarities subtest. [b]19 controls (n = 19), 7 mild (n = 8), and 6 moderate AD (n = 6) subjects completed the Similarities subtest.

each category was computed. The distribution indicated a fair amount of agreement among participants within the control and mild AD groups. For the animal terms, 27 out of 66 possible pairs of words were never grouped together by any of the controls; in the mild AD group, 26 out of 66 possible pairs were never grouped together. However, in the moderate AD group, only 9 out of 66 possible pairs were never grouped together; 19 pairs were grouped together by only 1 participant each. Thus, even though the participants in the moderate AD group formed a relatively homogeneous group with respect to demographic variables (see Table 1), their responses on the sorting task were less consistent than those of the mild AD and control groups. Consistency in sorting within the groups is reflected in the MDS scaling solutions (see Figure 1) and discussed below.

For the occupation terms, 14 out of 66 possible pairs of words were never grouped together by controls; 27 pairs were never grouped together by mild AD patients and 16 were never grouped together by moderate AD patients. The MDS solutions show that the pairs plumber/mechanic and dentist/doctor were among the most consistently sorted pairs for all groups (see Figure 2).

For the Kruskal (1964) method of MDS analysis, the individual matrices were summed by group (controls, mild–moderate AD combined, and mild AD, moderate AD groups separately) to construct summary matrices for each category which were then subjected to analyses with the ALSCAL multidimensional scaling program in SPSS-X (SPSS, Chicago, IL). These analyses provide a pictorial representation of the grouping data for each individual group by reducing the grouping data to a set of item-to-item distances (using the alternating least-squares approach; Young, Takane, & Lewyekyj, 1978) and then graphically representing those distances in a way that reflects the degree to which subjects within each group agreed that the items were similar. For example, high participant agreement that *cat* and *dog* were similar (i.e., all participants placed these two items within the same group) is reflected in an MDS solution in which *cat* and *dog* share a common or proximal point in the configuration. Representations from each group matrix were computed independently of each other group matrix. Inspection of the MDS representations gives a sense of how the groups sorted the 12 items in each category.

Because only 12 stimuli were presented, a two-dimensional solution was chosen for both categories based on the criteria set by Kruskal and Wish (1978) that the number of dimensions be four times less than the number of stimuli minus one [number of stimuli $- 1 \geq 4$ (dimension)]; exceeding this limit may seriously compromise the accuracy of the solution. In addition, for our data, two-dimensional solutions provided a better fit to the data as evaluated by Kruskal's (1964) stress formula (a measure of how well the resulting configuration represents the data—values near 0 indicate good fit) and R^2 (the linear variance accounted for by the solution) than did one-dimensional solutions in every case with the exception of the controls' sorting of animal terms that were somewhat better fit by a one-dimensional solution (stress = .01, $R^2 = 1.0$, compare these values to those in Table 2).

In addition, group summary matrices constructed from a subset of controls' animal and occupation sorts ($n = 6$ randomly chosen controls' data for each sort) were submitted to MDS analysis to see how smaller group sizes might affect the MDS solutions. The resulting solutions did not importantly differ, either by visual inspection or stress/R^2 levels (animals:

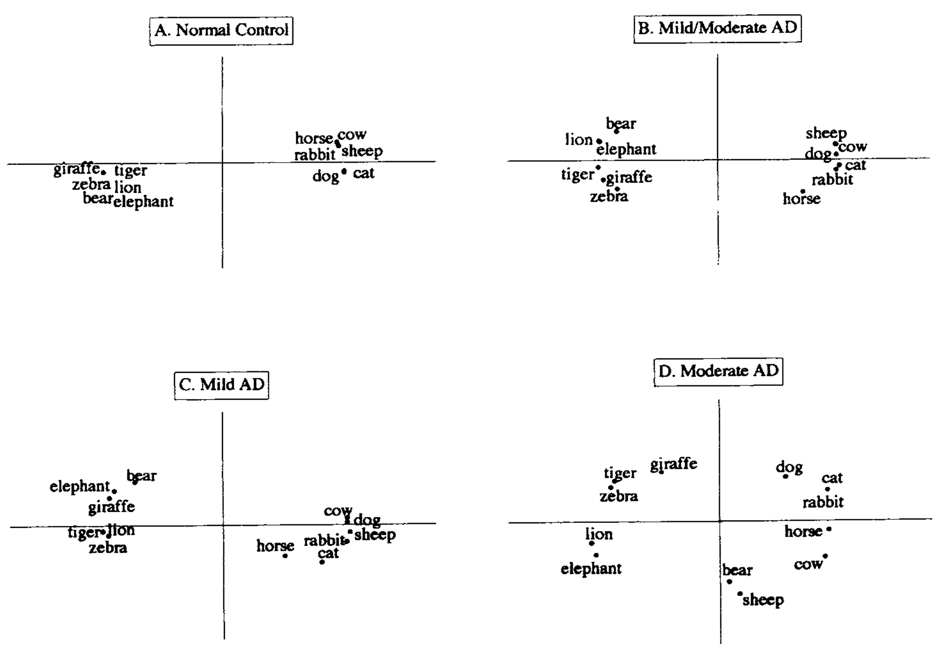

Figure 1. Animals: Semantic space organization of normal control, mild Alzheimer's disease patients (AD), and moderate AD (combined and separate) groups derived from multidimensional scaling analysis. Dimension 1 is represented on the horizontal axis and Dimension 2 on the vertical axis.

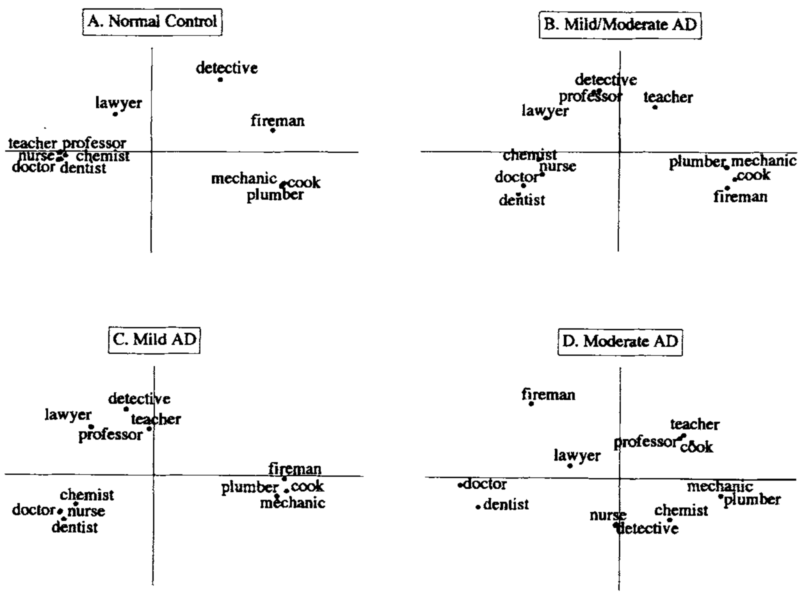

Figure 2. Occupations: Semantic space organization of normal control, mild Alzheimer's disease (AD), and moderate AD (combined and separate) groups derived from multidimensional scaling analysis. Dimension 1 is represented on the horizontal axis and Dimension 2 on the vertical axis.

stress = .02, R^2 = .99; occupations: stress = .12, R^2 = .93; compare these values with those in Table 2), from those obtained using the entire control group's data. Thus, the differences reported below do not simply reflect the smaller number of AD patients than controls. The solutions presented in Figures 1 and 2 were constructed with the entire control group's data.

Dimension interpretation is commonly accomplished by simply inspecting the configurations and intuiting dimension labels (Schiffman, Reynolds, & Young, 1981). Another approach is to present an additional task, such as a sorting task (Chan, Butters, Salmon, & McGuire, 1993). In the present study, dimension interpretation was aided by participants' explanations of their sorting schemes. Of course, AD patients, who commonly suffer from language deficits, were not expected to be able to give elaborate explanations; however, because the explanations served only as a guide for interpretation this was not a serious problem. Although the primary data are from the participants sorting of items participants' verbal explanations were quite interesting and informative concerning the kind of information that was available and could be articulated by participants. Mild and moderate AD groups' solutions are discussed separately; however, the MDS solutions for the combined mild–moderate AD data are also presented (see Figures 1 and 2). (It should be noted that the mild AD and moderate AD groups were not of equal size and therefore did not equally contribute to the resulting solution when both groups were combined.)

Table 2
Stress Level and Linear Variance in Multidimensional Scaling

Group	Stress	R^2
Control		
Animals	.03	1.0
Occupations	.18	.89
Mild to moderate AD		
Animals	.13	.94
Occupations	.22	.75
Mild AD		
Animals	.14	.93
Occupations	.15	.90
Moderate AD		
Animals	.18	.79
Occupations	.25	.65

Note. AD = Alzheimer's disease.

Animal Category

Controls. A good fit for these data is indicated by the low stress value of .03 and an R^2 value of 1.0 (these values are also presented in Table 2). Dimension 1, along the horizontal axis, appears to correspond to *wild* versus *domestic* (see Figure 1A). Note that the wild animals in the lower left quadrant all share the same point. Dimension 2 along the vertical axis is less clear-cut; however, it may reflect a further division of the domesticity concept: *dog* and *cat* are typically pets, whereas the animals in the upper right quadrant are most often found on farms. This interpretation is supported by verbal protocols (see example below). Furthermore, it appears that animals that are highly associated (e.g., *cat* and *dog*) are close together on the map (the two share a common point), thus providing evidence that the MDS technique is useful for capturing associative relationships.

From the verbal protocols, it is clear that these participants approached the task with the distinct strategy of looking for categories existing among the individual animal terms. As reflected by the low stress and perfect R^2 values, these participants tended to converge on similar groupings. The explanations offered by participants for their organizational scheme were typically concise, as in the following verbal protocol from Participant 516C:

Experimenter:	How is it that you organized this?
Participant:	There's six on top. Wild animals. What I'd call wild animals.
Experimenter:	Okay, the lion, tiger, elephant, zebra, giraffe, and bear.
Participant:	Correct. The dog and cat is [*sic*] a household animal. And then we have the horse, the cow, the sheep, and the rabbit are country or farm animals. That's what I have.

Mild AD. The mild AD patients also appeared to use the *wild* versus *domestic* distinction (see Dimension 1, Figure 1C). There appears to be slightly more dispersion of animal terms, indicative of less agreement among these participants as to the appropriate dimensions along which to sort the items, in contrast to the control group. Transcripts of verbalization during and following the grouping task indicate that they had more difficulty maintaining a coherent grouping strategy. Organization schemes were often characterized by the use of more subjective criteria; for example, 1 mild AD patient (511A) talked about her grouping pattern this way:

> Well, I put the cat and dog together, and once upon a time I might have put the dog on top and the cat underneath, but because I have a cat now I put the cat on top. So that's pet. Uh, the horse, the cow, the sheep, that's farm. That's food. Rabbit can be either way. It can be pet or it can be food. Then we have the lion, the tiger, the bear. They're dangerous animals. The elephant is a dangerous animal but can be tamed. Well, so can a lion, but an elephant can be working, so I sort of separated him. The zebra and a giraffe are more I see as gentle animals. A bear can also be trained, but a bear you never turn your back on, so I put him here.

Moderate AD. The moderate AD patients appeared to use dimensions of domesticity (see Dimension 1; Figure 1D) and, perhaps, size in their groupings. The solution shows a slight blurring of the *wild–domestic* distinction—note *bear* in lower right quadrant with domestic animals. The moderate AD patients showed even less capability than the mild AD patients of maintaining a global organizational strategy while doing this task. Often they were distracted by local relations between terms. This is reflected in the frequency analysis of pairs of terms placed together presented above and in the MDS solution as a greater spread of terms across quadrants. The moderate AD patients were substantially less able to communicate the bases for their sorting schemes. However, one particularly fluent patient (519A; MMSE = 16) explained:

Experimenter:	I want you to tell me how is it that you arranged these words like this.
Participant:	Well, I just followed the dog and the cat and the rabbit and the bear. They're all outside, you know, animals. The horse and the cow and the sheep—they're farm things.
Experimenter:	So the cat and the dog, why did you put them there?
Participant:	The cat and the dog, well that's the first thing that I would think of. I have a cat and I have a dog.
Experimenter:	Okay and the next one?
Participant:	But I don't have a rabbit. I have rabbits all around the house, but they're not in the house.
Experimenter:	And then the bear?
Participant:	They're nice. I think they're nice.
Experimenter:	The lion?
Participant:	Um hum.
Experimenter:	How is it that you arranged these other words the way that you have?
Participant:	Um, they sort of followed each other, I thought. The lion, the tiger, the zebra, and the horse. He's always around. The cow, you have to have him. And the sheep, they're cute, and the elephant.
Experimenter:	And what about the giraffe?
Participant:	The giraffe? He's all right.
Experimenter:	You mentioned (participant had spontaneously made this comment while sorting the items) that he's kind of like the elephant. Is that what you thought?
Participant:	Yeah.

Summary. The MDS solutions generated from these data acquired from the method of direct grouping bear similarities to the solutions obtained by Chan, Butters, Paulsen, et al. (1993) who used a verbal fluency task. They did not appear to be randomly generated. For example, the mild AD group solution presented here replicates the odd association *cow–dog,* also evident in the AD patients' map of Chan, Butters, Paulsen, et al. (1993), thus supporting the use of the present technique as an effective procedure. However, the method of direct grouping, supplemented with verbal protocols, suggests that more semantic information may be preserved than indicated by Chan, Butters, Paulsen, et al.'s results. In our study, it appears that mild AD patients were applying a domesticity distinction to their sorting pattern (6 of out of 9 mild AD patients mentioned this as a relevant distinction). Overall, the AD configurations (particularly the mild AD configuration) appear less distorted than the configurations reported by Chan, Butters, Paulsen, et al. (1993). The method of direct grouping is different from previously used methods in that it requires less in the way of generative and repeated intracategory judgments and may thus provide more favorable conditions for AD patients to display semantic knowledge.

Occupation Category

Controls. The controls appeared to use two relatively abstract dimensions in ordering the items (see Figure 2A).[1] Dimension 1 appears to reflect the relative educational requirements of the jobs (more years of school to the left), whereas Dimension 2 might be reflecting technical aspects of the occupations, that is, the lower quadrants include occupations that are involved with "fixing" either people (lower left) or things (lower right). A similar strategy was observed with the occupation items as with the animal items; typically participants followed a plan of looking for categories among the items.

Mild AD. The organization of the occupation terms according to the dimension of education (Dimension 1) as seen in the controls' map was largely preserved in this group's map (see Figure 2C). These participants appeared to use this relatively abstract dimension appropriately. From Figure 2C it also

[1] The original orientations of the two dimensions in the control groups' solution were reversed to provide consistency across solutions. The orientation of axes provided by the scaling program are arbitrary because distances are scaled and not axes.

appears mild AD patients made a distinction between medical and nonmedical occupations as well. Verbal explanations were characterized by less distraction and use of subjective criteria as compared with the animal's organization, as observed in Participant 512A's explanation:

> Well, this line [pointing to professor, teacher, lawyer, detective] is for people who are using their minds in order to solve things or teach things; strictly use of mind. These are people (pointing to dentist, doctor, nurse, chemist) who are using their skills in order to help people who need certain—how shall I say—medical or physical help. Here are the people [pointing to mechanic, plumber, cook, fireman] who help people keep the things that they own safe and viable.

Moderate AD. From Figure 2D, Dimension 1 no longer reflects education nor any other obvious categorization scheme. For Dimension 2, moderate AD patients' sortings seem somewhat respectful of the relations observed in the mild AD group. Again, these participants were substantially less communicative than mild AD patients and normal controls. Our more fluent participant (519A) said:

> Participant: I just followed the lawyer and the nurse and then the doctor. I figured they're all in the same kind of a category position. You know what I mean? They're all in a—the uh—medical business. Then the dentist and the chemistry, chemist. The professor, of course, he's in school, so then I followed it with the teacher. The plumber, that's mechanics. That's how I followed it through.
> Experimenter: Okay, anything else?
> Participant: No, the cook, she just got stuck in there.
> Experimenter: And the fireman also?
> Participant: And the fireman, yeah. He's necessary for any of these things, as far as I'm concerned.

Summary. For controls, there was somewhat less agreement in the sorting of these items as compared with the animal items, but both normal control and mild AD groups appeared to consider the relative educational requirements of the occupations as a relevant distinction for sorting. The technical aspects of the occupations (i.e., whether the occupations involved working with people or with things) was also an important distinction for these groups (5 out of 8 mild AD patients made explicit reference to this distinction). Furthermore, some pairs were consistently sorted together, even by the moderately AD patients: plumber/mechanic, dentist/doctor, and to a lesser degree, teacher/professor. Thus, although the map for the moderate patients is clearly different from that of normal and mild AD groups, these consistent pairings suggest that moderate AD patients were not randomly sorting the items. However, whereas the mild AD participants discovered and applied appropriate and interpretable distinctions to these relatively abstract items, the moderate AD patients appeared impaired in discovering and making use of the possible dimensions or relationships existing among the items. This is not to suggest that moderate AD patients did not distinguish among the concepts; clearly they did (mean number of groups formed = 5.67; see above), but the distinctions they made tended to be less encompassing and more idiosyncratic.

Discussion

These data are compatible with Chan, Butters, Salmon, and McGuire's (1993) finding that AD patients are less consistent in using any particular dimension and are more likely to use multiple dimensions when categorizing. That is, as reflected in the MDS solutions as greater spread among the terms for AD patients than controls, AD patients did not converge on similar distinctions to the same degree as normal controls and appeared more distracted by local relations between terms. However, the overall representations of the AD patients' grouping data are more similar to the controls' representation than might be expected, if these patients' semantic network were undergoing degradation such that they could no longer distinguish between same-category items. Local associations among several of the animal and occupation concepts appear to be relevant to these AD patients as reflected in the kinds of terms that were located together in the MDS solutions. It appears that the AD patients did not consistently discover the appropriate higher order categories existing among the items, as evident in the verbal reports obtained during and after the grouping task, as well as their MDS solutions.

These results further suggest that the organization of semantic knowledge may be less distorted in the mild stage of AD than previously recognized. Milder AD participants tended to sort within-category terms in a manner largely consistent with normal controls' performance and did not show evidence of inordinate reliance on concrete or perceptual attributes. Indeed, relatively abstract information was available to mild AD patients as particularly reflected in their sorting of occupation terms. Preservation of semantic knowledge in mild AD may have been less evident in previous work because of task demands, which in one case emphasized generative ability (Chan, Butters, Paulsen, et al., 1993) and in another the ability to make repeated deliberate and fine discriminations (Chan, Butters, Salmon, & McGuire, 1993; each of these studies tested primarily mild AD patients).

Semantic impairments in AD have been characterized as a process of attribute degradation, such that concepts are no longer distinguishable from each other (Martin, 1992; Martin & Fedio, 1983). Having observed error consistency for particular concepts across tasks in AD patients, other researchers suggest that AD may result in the functional loss of semantic concepts (Chertkow & Bub, 1990; Huff, Corkin, & Growdon, 1986). However, the performance of AD patients completing the grouping task in the present study indicates that they could distinguish and, in the case of the mild AD patients, appropriately verbalize relations between these same-category items. However, these participants did not appear as efficient in applying their knowledge as their matched normal control counterparts.

The present findings are compatible with the proposition that deficient use of a relatively intact semantic structure underlies the performance deficits observed in AD (Nebes, 1989), particularly when an effortful search of memory or a decision about semantic information is required (Nebes, Martin, & Horn, 1984). Hartman (1991) has characterized the primary deficit in AD as an inability to initiate and maintain an organized retrieval strategy. Keane, Gabrieli, Fennema, Growdon, and Corkin (1991) suggest that AD diminishes conceptual learning processes, whereas perceptual learning processes remain largely unaffected. These proposals are similar at a global level; that is, that AD can be broadly characterized as a deficiency in recruiting "attentional" processes in the performance of a task. We prefer to characterize the progression of AD as an increasing deficit in controlled or "reflectively" guided (Johnson, 1983) processing. For example, such a deficiency would serve to reduce the ability of AD patients to maintain active relevant information about the relationships among words, thereby affecting their ability to develop, apply, and consistently monitor their own strategy for sorting.

Our attempt to understand how AD affects cognitive functioning is guided by a proposed model of normal cognition from which aberrations in functioning can be described. MEM (multiple-entry modular memory system) is a theoretical framework in which memory is characterized as organized as two major systems: perceptual and reflective (Johnson, 1983; Johnson, 1992; Johnson & Hirst, 1993). The perceptual system is composed of a number of related processes which record and support information that is the consequence of perceptual processing. The reflective system is composed of those component processes that are necessary for the retrieval and manipulation of information for such purposes as planning, evaluating, and comparing. Normally these processes function under the strategic guidance of ongoing agendas, those processes that set goals and evaluate their outcomes. Agendas serve to activate and guide the subprocesses necessary for the completion of some task, whether it be to evaluate the relative importance of a concept's attributes or to guide the retrieval of animal terms (see Johnson & Hirst, 1993, for a more complete description of the agendas' roles).

Within this framework, the perceptual processes that result in semantic activation from perceptually processing words appear to remain largely intact (for example, observation of normal semantic priming in AD: Ober & Shenaut, 1994). The cognitive deficits resulting from AD could be interpreted as a consequence of a disruption in the connection between the goal-setting agendas and the reflective subprocesses necessary to meet them. This disruption in the agendas' functioning manifests itself in the present task as a difficulty in adopting a strategy to select the types of semantic relations that normal individuals usually select. Correct organization of within-category terms requires the ability to establish and maintain a goal, that is, to discover appropriate underlying dimensions and consistently apply these dimensions to the items.

Furthermore, it is expected that as the number of items to be evaluated is increased, heavier demands are made on the reflective system. For example, the functioning of reflective subprocesses is required for *noting* relations between the items and *shifting* to other aspects of meaning or attributes of the items. Because there are several items to be compared, one must be able to *refresh* earlier comparisons to keep them active for future comparisons, thereby permitting consistent use of dimensions. Finally, the ability to apply criteria for evaluating outcomes with respect to the active agenda is important in this task. The looser organization observed in the AD participants' MDS solutions suggests that they did not weight potentially distinguishing dimensions existing among the items as consistently as did controls.

With the present paradigm, we cannot distinguish which specific reflective processes (e.g., noting, shifting, refreshing, retrieving, maintaining agendas, etc.) are disrupted and to what degree. Furthermore, semantic memory in more moderately impaired AD patients may be undergoing a more far-reaching disruption in several reflective processes and perhaps structural deterioration as well. As the MEM framework makes clear, characterizing a deficit as a disruption of controlled processing, although part of the answer, is not a very specific answer. We have yet to identify deficient processes and process interactions that are reflected in AD participants performance across a range of tasks.

In conclusion, this study testifies to the availability of semantic knowledge in mild AD. Both AD and normal elderly individuals appear to appreciate some similar relationships among the items as shown by the MDS solutions (e.g., in the animal sort, all groups appreciate the domesticity distinction). However, the greater spread seen in the AD groups' solutions suggests they did not make use of the relationship information as broadly and consistently as controls. From their verbal explanations of their sorts, it appears that in addition to the criteria normal controls saw as important for distinguishing among the items, AD patients seemed willing to use other information. The patterns of organization and description seem to suggest that the primary semantic deficit observed in mild AD participants may be a consequence of severe disruption in reflective processing that allows one to selectively use some semantic information and ignore other semantic information rather than a loss of semantic information.

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