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Semantic Relations and Alzheimer's Disease: Typicality and Direction of Testing

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Alzheimer's disease (AD) patients and elderly controls verified semantic attributes of common concepts. For each attribute tested (superordinate category, part, property, and function), typicality of the semantic relation was varied, as well as the order in which relations were tested (e.g., category–concept or concept–category). Like controls, AD patients showed decreased accuracy and increased response times as typicality decreased across the range of attributes tested and for both test orders. Overall, the findings indicate that the early stages of AD result in a systematic deficit in which the relations among semantic concepts remain orderly rather than in a disordering of the relations among concepts. The findings are discussed in relation to 2 major theoretical interpretations of semantic deficits in AD: degraded structure and disrupted processing.

Studies directed at understanding the representation and use of general knowledge (or semantic memory, Tulving, 1972) suggest that conceptual information is represented as a graded structure. For example, some members of a category are judged more typical of the category or are more readily produced in response to their category name than others (Rosch & Mervis, 1975). Correspondingly, in verification tasks (e.g., "Is this a bird?"—*robin*) these more typical–high-dominance members are verified as being members of their category faster than are less typical–low-dominance members (Smith, Shoben, & Rips, 1974). This relation between typicality and latency to respond also holds for property statements; more typical properties of a concept (e.g., "A robin has feathers") are verified faster than are less typical properties (e.g., "A robin has legs"; Ashcraft, 1978; see also Smith & Medin, 1981, for a review). Another line of evidence regarding semantic organization comes from studies in which participants judge the similarity among concepts. Multidimensional scaling (MDS) of such similarity ratings often produces solutions suggesting that concepts within knowledge domains are organized according to two or three dimensions, for example, for animals, size and predacity (e.g., Henley, 1969). Typicality effects and the dimensions arising from MDS studies generally are taken as evidence that semantic memory is not a hodgepodge of associations, but rather an organized structure of meaningful relations among concepts.

An impairment of semantic memory is a core cognitive consequence of Alzheimer's disease (AD) with profound impact on comprehension, memory for events, thinking, planning, and communicating (Bayles & Kaszniak, 1987; Nebes, 1989). A number of clinical observations and performance deficits in laboratory tasks have been noted; for example, a patient might attempt to use objects inappropriately, have difficulty naming objects, or show impoverished recall of items from a category such as vegetables (see Bayles & Kaszniak, 1987; Gainotti, 1993; Nebes, 1989, 1992 for reviews). The primary question addressed by the present research is whether AD patients exhibit a systematic deficit that preserves normal typicality relations among concepts, even as their overall performance on tasks drawing on semantic concepts worsens, or whether AD results in a disordering of knowledge in which the organized quality of semantic memory is perturbed. As in the study of cognitively intact individuals, much previous research relevant for this issue comes from studies varying typicality of concepts in tasks such as naming, lexical decision, and verification of semantic relatedness (e.g., Cronin-Golomb, Keane, Kokodis, Corkin, & Growdon, 1992; Grober, Buschke, Kawas, & Fuld, 1985; Nebes, Boller, & Holland, 1986; Ober, Shenaut, Jagust, & Stillman, 1991) and from studies using MDS techniques to compare semantic organization of AD and control groups for a particular knowledge domain (Chan, Butters, Salmon, & McGuire, 1993; Chan, Butters, Paulsen, et al., 1993).

Taken together, previous investigations comparing the effects of typicality in AD and control groups have not produced a clear consensus about the impact of AD on semantic organization. Nebes et al. (1986) presented mildly to moder-

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ately impaired AD patients and matched controls with a category verification task including high- and low-dominance exemplars of categories. AD patients were affected much like controls by exemplar dominance. Comparable results were reported by Cronin-Golomb et al. (1992), who also used a category verification task with high- and low-dominance target exemplars for a variety of categories. Cronin-Golomb et al. also presented study participants with the name of a superordinate category and three exemplars differing in typicality (e.g., vegetables: *carrot, onion,* and *turnip*). They were asked to choose the most typical and then the most typical of the two remaining exemplars. There was no difference between elderly controls and AD patients in number of items for which all three exemplars were correctly ranked. Conceptual relations other than category–exemplar pairs have also been investigated. Nebes and Brady (1990) used a relatedness verification task ("Is this word [attribute] related to a [noun]?") in which attribute dominance was manipulated. Error rates and latencies to respond in AD patients and controls were affected similarly by attribute dominance. (The type of attribute, e.g., part, property, or function, was not systematically compared.)

In contrast, Grober et al. (1985) reported data suggesting that patients with dementia do not exhibit a graded organization among semantic relations. Each test noun (e.g., *airplane*) was presented with the instruction to the participant to "think about the word's meaning." This was followed by the presentation of three words, selected because of their essential (e.g., *fly*), nonessential (e.g., *luggage*), and intermediate (e.g., *radar*) importance to the test noun. Participants were instructed to "choose the word that was most important to the concept." After each choice by the participant, the chosen item was removed, and the participant was instructed to choose from the remaining two "which word was next in importance to the concept." Patients with dementia ordered significantly fewer triples correctly than did controls; however, their performance was better than would be expected by chance. Additional analysis indicated that the patients with dementia considered the essential attributes to be less important to the meaning of the concept three times more often than the normal controls. Grober et al. concluded that performance of dementia patients reflects a disruption in the relative salience of conceptual attributes, that is, a disorganization of semantic knowledge.

Chan and colleagues (Chan, Butters, Paulsen, et al., 1993; Chan, Butters, Salmon, & McGuire, 1993) used multidimensional scaling to characterize the structures of AD patients and controls for the semantic space of animal concepts (e.g., *dog, bear,* and *giraffe*). Data were obtained from participants' free generation of animal names (a verbal fluency task; Chan, Butters, Paulsen, et al., 1993) or from a task in which participants selected the two most similar from three items on each trial (Chan, Butters, Salmon, & McGuire, 1993). In both cases, the MDS solutions reflected more variability among AD patients than controls and less convergence on one or two dimensions, suggesting a disorganization of semantic knowledge.

In summary, some of these studies reported effects suggesting preserved semantic organization in AD patients and some did not. A number of factors are not constant across the above studies, such as type of semantic relation investigated and the task the participants were asked to perform. Also of course, AD groups may on average have been at somewhat different stages of the disease across the studies. Thus it is not possible to characterize the overall pattern of semantic disruption among concepts in AD with confidence. The present study was an attempt to remedy this situation by holding task constant and systematically investigating typicality effects for four types of semantic relations: categories, parts, properties, and functions. A number of investigators have suggested that in AD category information may be preserved relative to information about other attributes (Chertkow, Bub, & Seidenberg, 1989; Martin & Fedio, 1983; Warrington, 1975; but see Nebes & Brady, 1988). If so, category judgments may be more likely to show an intact organization in terms of typicality than judgments about other semantic attributes.

An additional variable investigated was the direction in which the semantic relation was tested. Semantic memory studies with AD patients have usually investigated the relation between concepts and their attributes in only one direction: Given a picture of an object or the name of a concept, participants are asked to make a response concerning the concepts' attributes, for example, its category membership (Chertkow et al., 1989; Nebes & Brady, 1988; Warrington, 1975). One exception is Ober et al. (1991), in which direction was investigated in category–exemplar pairs. In this case, direction (category–concept, e.g., *fruit–orange*; concept–category, e.g., *orange–fruit*) did not affect response times to the second item for either the normal or AD groups in either naming or lexical decision tasks. However, direction may be more important in accessing attributes other than category membership if AD patients are especially impaired on these other attributes.

In summary, the major purpose of the present study was to characterize the performance deficit of AD patients on semantic relations that differ in typicality. Potential theoretical interpretations of obtained performance deficits are considered in the Discussion section.

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 area physicians and clinics in New Jersey and Pennsylvania . Normal elderly controls matched for age, gender, and education were in most instances spouses of patients. Five elderly controls were recruited from retirement communities in the Princeton, New Jersey, area as matched controls for patients without spouses.

The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was administered to assess stage of AD. We classified individuals as mildly demented if their MMSE scores were 19 or above (maximum score = 30); patients with scores of 18 or less were classified as moderately demented. Twenty-four AD patients (9 with moderate and 15 with mild dementia) and 24 elderly controls were tested in the category and part studies. Fourteen of these AD patients (5 with moderate and 9 with mild dementia) and 14 elderly controls

Table 1
Demographic and Psychometric Characteristics of Alzheimer Disease (AD) Patients and Controls

	Gender (*n*)		Age (years)		Education (years)		MMSE[a]	
Group	Female	Male	*M*	*SE*	*M*	*SE*	*M*	*SE*
			Categories and parts					
Controls	12	12	72.7	1.7	13.3	0.67	28.3[b]	0.46
Alzheimer's								
Mild	11	4	73.0	1.8	13.6	1.10	22.4	0.50
Moderate–severe	4	5	71.4	3.4	13.1	0.95	14.7	1.70
			Properties and functions					
Controls	6	8	75.6	1.5	13.2	0.66	28.3	0.46
Alzheimer's								
Mild	7	2	74.4	2.3	12.7	1.20	22.6	0.75
Moderate–severe	4	1	74.2	3.6	11.2	0.80	13.0	2.90

[a]MMSE = Mini-Mental State Examination (maximum score = 30). [b]Only 14 of the 24 elderly controls were administered the MMSE.

were also tested in the property and function studies (the property and function studies were incorporated in testing sessions somewhat later). Table 1 shows the gender, mean ages, years of education, and MMSE scores for participants tested on categories and parts and on properties and functions.

Materials and Procedure

The materials consisted of various common concepts and corresponding high-, medium-, and low-typicality items for the relevant attribute. Examples include (category) *cloth–cotton, satin,* or *burlap*; (part) *bicycle–wheels, gears,* or *basket*; (property) *plum–purple, round,* or *sour*; and (function) *cup–sip, measure,* or *scoop.* A wide range of concepts were obtained from published norms (Ashcraft, 1978; Battig & Montague, 1969; McEvoy & Nelson, 1982; Shapiro & Palermo, 1970; Tversky & Hemenway, 1984) or generated by the experimenters. Criteria stipulated that the concept be familiar to normal adults and that it share category membership with at least two other items or have at least three identifiable parts, properties, or possible functions. Normative data for establishing typicality of these items were then collected by obtaining ratings from Princeton University students. (Details of the norming study are available from the authors.) The items used in the studies reported here were selected to minimize repetitions of items within and across attribute lists in order to avoid uncontrolled sources of positive or negative priming. Most of the target concepts were common objects (e.g., *bicycle*), but some were more abstract (e.g., *rain* or *pity*).

For each attribute study, three test lists were made up so that the high-, medium-, and low-typical items for any particular concept were assigned to different lists. Each participant serving in a given study received one list testing three levels of typicality relation for a particular attribute type without repeating concepts within any given list. Within each attribute study, the three lists were equated for overall frequency (Francis & Kučera, 1982), typicality, word length, and number of syllables. Each category list consisted of 30 concept–category pairs, 10 at each level of typicality, and 16 foils. The part, property, and function lists consisted of, respectively, 18 concept–part, concept–property, and concept–function pairs, 6 at each level of typicality, and 10 foils. For foils, there were no relations between the two concepts (e.g., "Is this a kind of direction"—*pork*). Within each list, half of the pairs were tested in the concept–attribute condition: participants heard the word referring to the target concept and were then shown the word designating an attribute on the computer screen (e.g., "Is this a category for collie?"—*dog*). The other half were tested in the attribute–concept condition: participants heard the attribute in the question and were then shown the word for the object on the computer screen (e.g., "Is this a kind of dog?"—*collie*). The experimental trials were blocked by direction of semantic relation. Within a block, items from the three levels of typicality and foils were intermixed randomly. The different levels of attribute typicality and direction for a given concept were counterbalanced across participants, as was the order in which attributes were tested.

The participant responded by verbally answering yes or no as quickly as possible, and the experimenter immediately pressed a key on the keyboard to record the participant's response. We did not ask participants to press buttons or speak into a voice key in order to eliminate extra task requirements (keeping track of which button is which or inhibiting irrelevant vocalizations such as coughing or clearing throats) that might create a greater cognitive burden on AD patients than controls. However, we recorded the time from the appearance of the word on the screen to the experimenter's keypress. Although the experimenter's response contributed to absolute response times, we were not particularly interested in absolute response times (AD patients generally respond more slowly than controls), but rather in potential interactions of typicality with participant group.

Results

Performance on each attribute was evaluated separately, but for ease of discussion results for comparable analyses of all four attributes were considered together. All results reported are significant at $p < .05$.

Table 2 shows the mean overall accuracy (proportion correct

Table 2
Proportion Correct Responses to Targets Minus Proportion of Incorrect Responses to Foils

	Group			
	Control		AD	
Attribute	*M*	*SE*	*M*	*SE*
Category	.92	.02	.78	.04
Part	.95	.02	.78	.04
Property	.83	.02	.68	.06
Function	.84	.02	.71	.05

Note. AD = Alzheimer's disease.

yes responses to targets minus proportion incorrect yes responses to foils). As shown in Table 2, AD patients were less accurate than controls for all attributes tested: categories, $F(1, 46) = 10.59$, $MSE = .02$; parts, $F(1, 46) = 16.91$, $MSE = .02$; properties, $F(1, 26) = 5.05$, $MSE = .03$; and functions, $F(1, 26) = 6.36$, $MSE = .02$.

To assess the effects of typicality for each attribute type, we analyzed the proportions of correct responses to targets as a 2 (Group: controls or AD) × 3 (Typicality: high, medium, or low) × 2 (Direction: concept–attribute or attribute–concept) analysis of variance (ANOVA). The means, collapsed across direction, are shown in Table 3. The analyses contrasted controls with AD patients regardless of severity. However, the means are also shown separately for mildly and moderately affected AD patients in Figure 1 for comparison. There were main effects of typicality and no significant Group × Typicality interactions for all attributes tested: categories, $F(2, 92) = 13.96$, $MSE = .01$; parts, $F(2, 92) = 6.39$, $MSE = .02$; properties, $F(2, 52) = 11.33$, $MSE = .05$; and functions, $F(2, 52) = 13.14$, $MSE = .05$. The only significant effects involving direction of testing were for categories, which showed both a main effect of direction, $F(1, 46) = 11.90$, $MSE = .01$, and a Group × Direction interaction, $F(1, 46) = 4.59$, $MSE = .01$. This interaction reflects that the accuracy of controls did not differ when items were tested in the category–concept direction (e.g., *cloth–cotton;* .97) and when tested in the concept–category direction (e.g., *cotton–cloth;* .95), $F < 1$. In contrast, AD patients were more accurate in the category–concept direction (.96) than concept–category direction (.89), $F(1, 46) = 15.64$, $MSE = .01$. There were no other significant main effects (other than group) or interactions.

For each attribute type, the median response times (in seconds) for correct responses to targets were analyzed as a 2 (Group: controls or AD patients) × 3 (Typicality: high, medium, or low) × 2 (Direction: concept–attribute, attribute–concept) ANOVA (see Table 4). The means are also shown separately for mildly and moderately affected AD patients in Figure 2. As shown in Table 4 and in Figure 2, there were main effects of typicality for all attributes tested. Response times increased as typicality decreased: categories, $F(2, 92) = 9.34$, $MSE = .12$; parts, $F(2, 92) = 9.43$, $MSE = .69$; properties, $F(2, 48) = 12.71$, $MSE = .97$; and functions, $F(2, 46) = 9.69$, $MSE = .83$. For categories, there was also a main effect of direction, $F(1, 46) = 20.48$, $MSE = .18$, and a Group × Direction interaction, $F(1, 46) = 14.06$, $MSE = .18$. Paralleling the accuracy data, this interaction arises because the response times did not differ for controls in the category–concept (.93 s) and concept–category (.97 s) directions, $F < 1$, whereas AD patients were faster to respond in the category–concept (1.4 s) than concept–category (1.8 s) direction, $F(1, 46) = 34.24$, $MSE = .18$. For parts, there was a Direction × Typicality effect, $F(2, 92) = 4.33$, $MSE = .78$, but this did not interact with group and is not discussed further in this article.

Finally, for functions, there was a significant Group ×

Table 3
Mean Proportion Correct for Targets of Alzheimer Disease (AD) Patients and Elderly Controls

	Typicality					
	High		Medium		Low	
Attribute	*M*	*SE*	*M*	*SE*	*M*	*SE*
			Controls			
Category	1.00	0	.96	.01	.93	.01
Part	1.00	0	.94	.02	.95	.02
Property	1.00	0	.90	.03	.81	.05
Function	.98	.02	.93	.04	.81	.05
			AD group			
Category	.96	.01	.92	.02	.88	.02
Part	.95	.02	.88	.03	.86	.03
Property	.93	.03	.82	.04	.71	.06
Function	.98	.02	.86	.03	.70	.06

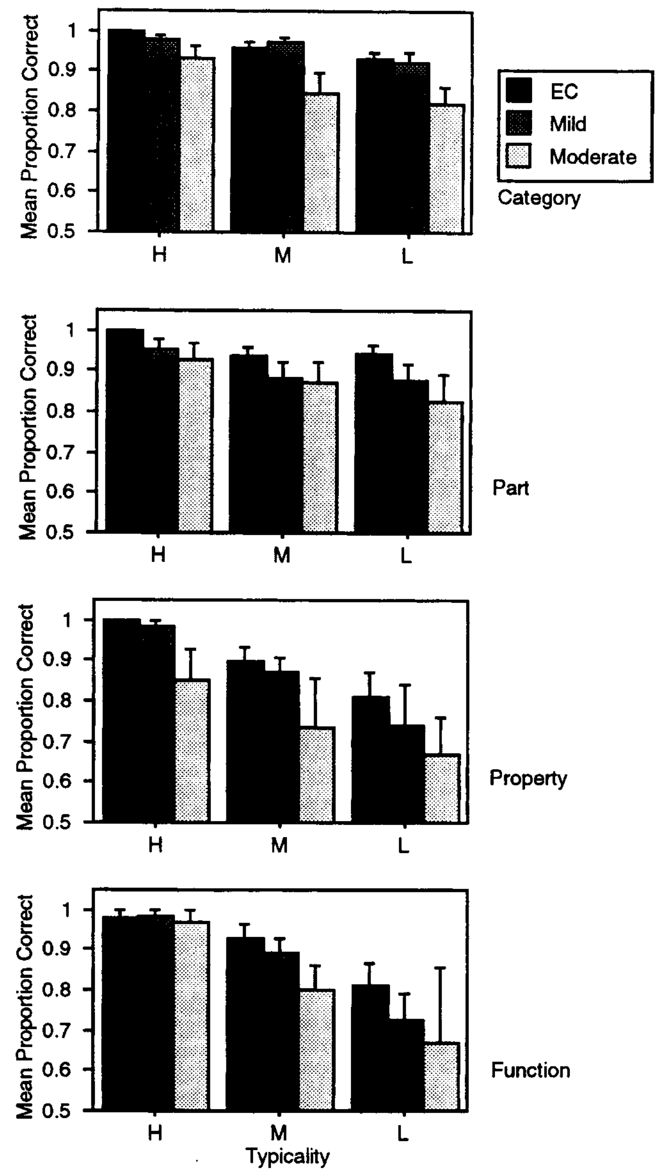

Figure 1. Mean accuracy (hits–false positives) for elderly controls (EC) and people with mild or moderate Alzheimer's disease. Error bars indicate standard error of the mean. H, M, and L = high, medium, and low typicality, respectively.

Typicality interaction, $F(2, 46) = 3.35$, $MSE = .83$. As shown in Table 4 and in Figure 2, AD patients appeared to have increasing difficulty as typicality decreased. The low-typical functions did not appear more difficult for the controls compared with the low-typical items for other attribute types. There were no other significant main effects (other than group) or interactions. Furthermore, high-, medium-, and low-typicality function items did not differ in mean number of syllables, letters, or frequency[1] (Francis & Kučera, 1982), all $Fs < 1$. Therefore, the Group × Typicality interaction for functions shown in Figure 2 does not appear to be a consequence of differences in these item features across levels of typicality.

Discussion

This investigation of semantic memory in AD patients required participants to verify four types of relations between concepts and attributes: category, part, property, and function. We varied the typicality (high, medium, or low) of the relations tested and the direction in which they were tested (e.g., concept–attribute, attribute–concept) in order to derive a more general picture of semantic deficits in AD than was available from prior studies. The major finding was that patients demonstrated robust typicality effects across all four types of semantic relations and both orders of testing. Evidently, although use of semantic memory clearly worsens as the disease progresses in the mild-to-moderate range, as evidenced by the poorer accuracy and slower response times of AD patients, conceptual knowledge remains organized in an orderly and relatively normal way.

As suggested in the introduction, this pattern of typicality findings shows a systematic deficit rather than a disordering of semantic memory in which the relative saliency of attributes or exemplars of concepts is disorganized. Whatever the mechanism producing this deficit, at least in the mild-to-moderate stages of AD investigated here, it appears to operate in such a manner that the relative rank ordering of accessibility of attributes is preserved. This conclusion is consistent with a number of other studies cited in the introduction (Cronin-Golomb et al., 1992; Nebes et al., 1986; Nebes & Brady, 1990)

Table 4
Median Response Times (in Seconds) for Targets of Alzheimer Disease (AD) Patients and Elderly Controls

	Typicality					
	High		Medium		Low	
Attribute	*M*	*SE*	*M*	*SE*	*M*	*SE*
			Controls			
Category	0.89	.03	0.94	.03	1.03	.03
Part	0.90	.03	1.05	.04	1.24	.07
Property	1.09	.03	1.53	.23	1.83	.22
Function	1.15	.07	1.30	.08	1.49	.10
			AD group			
Category	1.47	.13	1.65	.12	1.76	.13
Part	1.51	.18	2.18	.26	2.13	.22
Property	1.82	.18	2.35	.40	3.03	.46
Function	1.78	.27	2.18	.32	3.02	.50

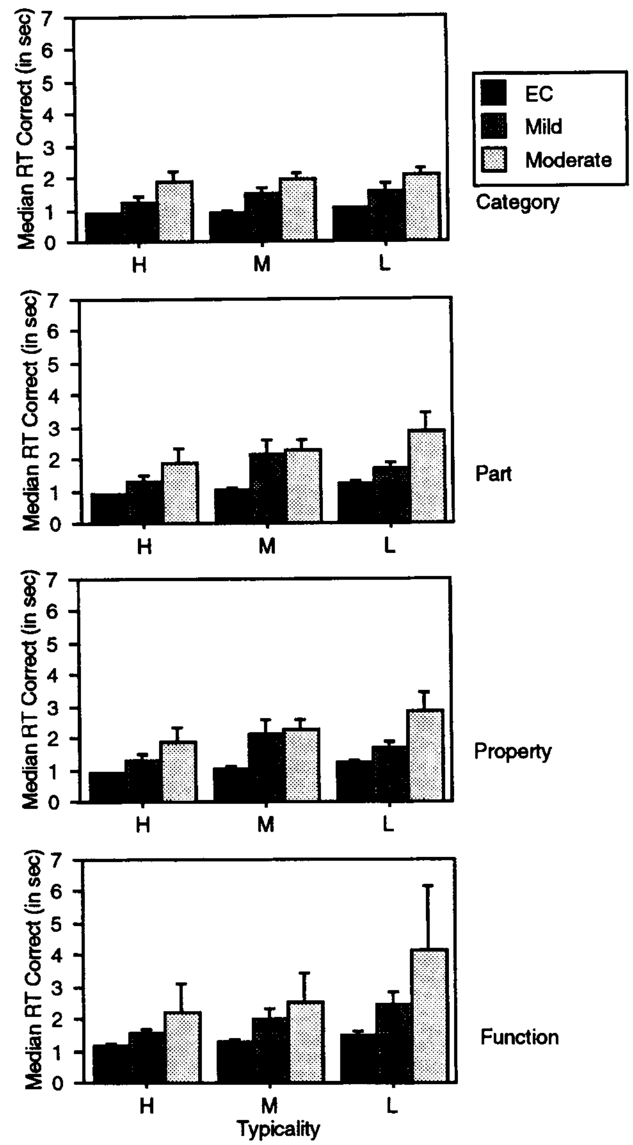

Figure 2. Median response times (RT; in seconds) for correct responses to targets by elderly controls (EC) and people with mild or moderate Alzheimer's disease. Error bars indicate standard error of the mean. H, M, and L = high, medium, and low typicality, respectively.

and different from that reached by Grober et al. (1985) and more recently by Chan and colleagues (Chan, Butters, Salmon, & McGuire, 1993; Chan, Butters, Paulsen, et al., 1993).

One explanation of the inconsistency in findings across laboratories is that the tasks that appear to show a disordering of semantic structure have more difficult processing requirements than the tasks that show preserved relative order among concepts (cf. Bayles, Tomoeda, Kaszniak, & Trosset, 1991). The free generation (verbal fluency) task used by Chan,

[1] Francis and Kučera (1982) values were available for 15, 15, and 14 of the 18 function items in each of high-, medium-, and low-typicality conditions, respectively.

Butters, Paulsen, et al. (1993) may be especially susceptible to retrieval or strategy differences between groups (Mandler, 1975). Furthermore, the task of picking the most similar of three items (Chan, Butters, Salmon, & McGuire, 1993) may be, like Grober et al.'s (1985) task of picking the most important of three attributes, too large a cognitive load or create unmanageable interitem interference for AD patients. However, it should also be noted that Cronin-Golomb et al.'s (1992) AD patients showed intact typicality relations for category exemplars in a task quite similar to that used by Grober et al. It may be that category relations are less subject to interference from competing alternatives than are other relations such as parts, properties, and functions.

Some support for the idea that retrieval and strategy deficits may exaggerate apparent impairment of semantic organization comes from a study of semantic structure in AD patients in which we obtained MDS solutions for the domains of animals and occupations. We used a task in which patients were given the words printed on individual cards and simply had to place cards together on the table corresponding to the items that went together (Bonilla & Johnson, 1995). With this simpler task, both the MDS solutions and the participants' descriptions of why they grouped certain items together suggested that at least for animals AD patients may have lost less attribute information about concepts than indicated by analyses of Chan, Butters, Paulsen, et al. (1993). Rather, our AD patients seemed to have had difficulty consistently using only a subset of this attribute information (e.g., domesticity) about animals to order the concepts in this task.

The direction in which questions about semantic relations were asked significantly influenced the accuracy performance of AD patients only for categories; concept–attribute pairs were more difficult than were attribute–concept pairs. The finding that direction of testing may matter in assessing semantic deficits in AD is important because the majority of semantic knowledge studies of AD patients have used concept–attribute pairings exclusively. Our findings suggest that the concept–attribute direction of testing may be a disadvantage to AD patients, perhaps exaggerating the amount of attribute knowledge that seems "lost."

Currently, there are two major classes of interpretations of the semantic deficit in AD patients. According to one proposal (e.g., Chan, Butters, Salmon, & McGuire, 1993), performance deficits reflect the deterioration of the underlying structure, that is, a degrading of the associations among concepts (degraded structure hypothesis). According to another proposal (e.g., Hartman, 1991; Nebes, Martin, & Horn, 1984), performance deficits reflect difficulty accessing and using information from a largely intact set of semantic relations (disrupted processing hypothesis). The present study provides an asymmetrical test between these hypotheses. Reduced or no typicality effects for AD patients would strongly indicate that the semantic network is degrading structurally. In contrast, the outcome that we did obtain, normal typicality effects (except perhaps for functions, for which AD patients showed an increased typicality effect relative to controls; see below) can be accommodated by either the disrupted processing or the degraded structure hypotheses.

There are several ways to characterize a processing deficit that could produce an overall but systematic deficit in semantic tasks. A processing deficit could arise from a reduced level of activation in the system as a whole (e.g., Milberg, Blumstein, Katz, Gershberg, & Brown, 1995). Reduced activation would produce an overall deficit in use of semantic information but could leave relative typicality relations intact. Alternatively, the concepts activated by a test item (i.e., presentation of an object or attribute concept) presumably activate a host of features, knowledge, or episodic memories associated with that concept. Subsequently narrowing the activation to the specific feature in question may require inhibitory processes to reduce activation of competing concepts (e.g., Hasher & Zacks, 1988). Yet another possibility is that focusing on a specific feature may require reflective mechanisms such as refreshing, noting, or retrieving that are recruited by task agendas and that contribute to increasing or maintaining activation of some concepts over others or to selection among them (e.g., Johnson, 1992). AD then might involve deficits in inhibitory (Balota & Duchek, 1991) or reflective processes (e.g., Bonilla & Johnson, 1995; Hartman, 1991; Nebes, 1989), or perhaps in both. Neither inhibitory nor reflective deficits would necessarily disorder the typicality relations among concepts.

Although an interpretation of the pattern of results in terms of a processing deficit seems reasonable, it is not conclusive. Typicality effects could arise from a deteriorating network as well. Typicality effects could occur in a degraded structure if we assume that structural degrading does not disorganize the network but simply falls equally across it, weakening associations at all levels of typicality, but not disturbing the relative strengths (or distances) among concepts.

Finally, it is worth noting that the response time data suggest that AD patients had an increasing deficit on functions as typicality decreased (see Table 4 and Figure 2). The fact that AD patients' performance might be more sensitive to typicality effects for functions than for other attributes is quite intriguing. The present study permits only qualitative comparisons across attributes because typicality and word frequency levels were not equated across types of attributes. However, Figure 2 suggests that we can rule out the possibility that low-function items were particularly difficult on the basis of the performance of elderly controls; controls did not appear to have particular difficulties on low-typical functions relative to low-typical attributes of other types. Thus, it appears that functions might be more sensitive than other attributes to cognitive deficits resulting from AD, and it seems worth speculating about potential mechanisms.

One possibility is that accessing functional knowledge requires more activation or more processing operations (either inhibition or reflective activation) than other semantic attributes. For example, functions often depend on knowledge of parts and properties (e.g., Roy & Square, 1985; Tversky & Hemenway, 1984). Also, functions may be more cognitively complex than other attributes. That is, parts and properties are inherent in the perceptual characteristics or basic meanings of individual concepts, whereas functions are relations between concepts (e.g., *spoon* and *coffee* are two concepts related through the spoon's stirring function). In that functions tend to express relations, they tend to be more abstract than parts and properties. If functions require activation to spread farther or be distributed among more concepts, the effect of any decrease in the amount of automatic activation would fall disproportionately on functions, especially low-typical functions. Similarly, any disruption of inhibitory processes that may suppress irrelevant information or of reflective processes that maintain activation or select among activated concepts or retrieve additional concepts (e.g., *coffee*) would fall disproportionately on functions, especially low-typical functions. Although these various disrupted processing accounts could accommodate AD patients' increasing impairment as typicality of function decreases, a degrading structure could also produce a similar pattern. For example, if the number of concepts required for understanding functions increases as typicality decreases, any deterioration of the semantic structure would increase the probability that at least one association needed to derive a particular functional relation was degraded.

In summary, our results show that the earlier stages of AD do not so much produce a disorganization of semantic information as some sort of impairment in which relative salience or accessibility of concepts is maintained (i.e., a systematic deficit). As the disease progresses from the mild to moderate stage, a remarkably orderly organization of the relations among semantic concepts continues to be reflected in participants' performance. This orderly pattern must be accommodated by either disrupted processing or degraded structure accounts of semantic impairment in AD.

References

Ashcraft, M. H. (1978). Property dominance and typicality effects in property statement verification. *Journal of Verbal Learning and Verbal Behavior, 17,* 155–164.

Battig, W. F., & Montague, W. E. (1969). Category norms for verbal items in 56 categories: A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology Monographs, 80*(3, Pt. 2).

Balota, D. A., & Duchek, J. M. (1991). Semantic priming effects, lexical repetition effects, and contextual disambiguation effects in healthy aged individuals and individuals with senile dementia of the Alzheimer type. *Brain and Language, 40,* 181–201.

Bayles, K., & Kaszniak, A. W. (1987). *Communication and cognition in normal aging and dementia.* Boston: Little, Brown and Company.

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.

Chan, A. S., Butters, N., Paulsen, J. S., Salmon, D. P., Swenson, M. R., & Maloney, L. T. (1993). 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., & McGuire, K. A. (1993). Dimensionality and clustering in the semantic network of patients with Alzheimer's disease. *Psychology and Aging, 8,* 411–419.

Chertkow, H., Bub, D., & Seidenberg, M. (1989). Priming and semantic memory loss in Alzheimer's disease. *Brain and Language, 36,* 420–446.

Cronin-Golomb, A., Keane, M. M., Kokodis, A., Corkin, S., & Growdon, J. H. (1992). Category knowledge in Alzheimer's disease: Normal organization and a general retrieval deficit. *Psychology and Aging, 7,* 359–366.

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

Francis, W. N., & Kučera, H. (1982). *Frequency analysis of English usage.* Boston: Houghton Mifflin.

Gainotti, G. (1993). Mechanisms underlying semantic–lexical disorders in Alzheimer's disease. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (Vol. 8, pp. 283–294). New York: Elsevier Science.

Grober, E., Buschke, H., Kawas, C., & Fuld, P. (1985). Impaired ranking of semantic attributes in dementia. *Brain and Language, 26,* 276–286.

Hartman, M. (1991). The use of semantic knowledge in Alzheimer's disease: Evidence for impairments of attention. *Neuropsychologia, 29,* 213–228.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and new view. In G. M. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). New York: Academic Press.

Henley, N. M. (1969). A psychological study of the semantics of animal terms. *Journal of Verbal Learning and Verbal Behavior, 8,* 176–184.

Johnson, M. K. (1992). MEM: Mechanisms of recollection. *Journal of Cognitive Neuroscience, 4,* 268–280.

Mandler, G. (1975). Memory storage and retrieval: Some limits on the reach of attention and consciousness. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 499–516). New York: Academic Press.

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

McEvoy, C. L., & Nelson, D. L. (1982). Category name and instance norms for 106 categories of various sizes. *American Journal of Psychology, 95,* 581–634.

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.

Milberg, W., Blumstein, S. E., Katz, D., Gershberg, F, & Brown, T.. (1995). Semantic facilitation in aphasia: Effects of time and expectancy. *Journal of Cognitive Neuroscience 7,* 33–50.

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

Nebes, R. D. (1992). Cognitive dysfunction in Alzheimer's disease. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 373–446). Hillsdale, NJ: Erlbaum.

Nebes, R. D., Boller, F., & Holland, A. (1986). Use of semantic context by patients with Alzheimer's disease. *Psychology and Aging, 1,* 261–269.

Nebes, R. D., & Brady, C. B. (1988). Integrity of semantic fields in Alzheimer's disease. *Cortex, 24,* 291–300.

Nebes, R. D., & Brady, C. B. (1990). Preserved organization of semantic attributes in Alzheimer's disease. *Psychology and Aging, 5,* 574–579.

Nebes, R. D., Martin, D. C., & Horn, L. C. (1984). Sparing of semantic memory in Alzheimer's disease. *Journal of Abnormal Psychology, 93,* 321–330.

Ober, B. A., Shenaut, G. K., Jagust, W. J., & Stillman, R. C. (1991). Automatic semantic priming with various category relations in Alzheimer's disease and normal aging. *Psychology and Aging, 6,* 647–660.

Rosch, E. H., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology, 7,* 573–605.

Roy, E. A., & Square, P. A. (1985). Common considerations in the study of limb, verbal and oral apraxia. In E. A. Roy (Ed.), *Advances in psychology: Neuropsychological studies of apraxia and related disorders* (Vol. 23, pp. 111–161). New York: Elsevier Science.

Shapiro, S. I., & Palermo, D. S. (1970). Conceptual organization and class membership: Normative data for representatives of 100 categories. *Psychonomic Monograph Supplements, 3*(11, Whole No. 43).

Smith, E. E., & Medin, D. L. (1981). *Categories and concepts.* Cambridge, MA: Harvard University Press.

Smith, E. E., Shoben, E. J., & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review, 81,* 214–241.

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

Tversky, B., & Hemenway, K. (1984). Objects, parts, and categories. *Journal of Experimental Psychology: General, 113,* 169–197.

Warrington, E. K. (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology, 27,* 635–657.

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