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The Spectrum of Category Effects in Object and Action Knowledge in Dementia of the Alzheimer's Type

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The validity and origin of category effects in the anomia demonstrated by individuals with dementia of the Alzheimer's type (DAT) remains controversial. Twenty DAT subjects were tested with picture naming and semantic association judgment tests. Picture and word stimuli were drawn from biological, nonbiological, and actions–verbs categories, all of equal difficulty and previously normed on elderly controls. DAT subjects made significantly more naming and semantic judgment errors in the biological category than in the nonbiological category. They were relatively more accurate in naming and making judgments for actions–verbs when presented as words or as 5-s animations. When line drawings of actions were shown for naming, performance deteriorated significantly. Converging results from these 2 tasks provide strong evidence for a semantic memory impairment preferentially affecting biological items to a greater extent than nonbiological items or action verbs in DAT.

Difficulty naming objects, or anomia, is one of the major problems early in the course of dementia of the Alzheimer's type (DAT). Studies with DAT patients have suggested several factors that can contribute to their impaired performance on experimental naming tasks. Some researchers have proposed that visuoperceptual factors can account for a significant portion of the naming impairment in some patients (Cormier, Margison, & Fisk, 1991; Mendez, Mendez, Martin, Smyth, & Whitehouse, 1990). Others have pointed to a lexical–phonological retrieval deficit in DAT (Astell & Harley, 1998; Biassou et al., 1995). The majority of studies, however, have ascribed naming problems in DAT to semantic memory (Chertkow & Bub, 1990; Hodges, Patterson, Graham, & Dawson, 1996; Huff, Corkin, & Growdon, 1986; Martin & Fedio, 1983). These latter studies emphasize a characteristic deterioration of semantic memory that occurs in DAT.

Detailed studies of mild and moderate DAT patients also have demonstrated the presence of category effects in their picture naming performance. For example, Silveri, Daniele, Giustolisi, and Gainotti (1991) showed in a study with 15 DAT subjects that they had a category-specific naming impairment for living things compared with nonliving things. This observation has subsequently been replicated in other studies (Daum, Riesch, Sartori, & Birbaumer, 1996; Mauri, Daum, Sartori, Riesch, & Birbaumer, 1994; Mazzoni, Moretti, Lucchini, Vista, & Muratorio, 1991). Whereas most naming studies have focused on concrete nouns, Robinson, Grossman, White-Devine, and D'Esposito (1996) raised the possibility that DAT patients might be more impaired in action naming than in object naming. They found a small but consistent disadvantage for naming with verbs than naming with nouns in the majority of the 20 DAT subjects tested in their study. Further evidence comes from a study by Cappa et al. (1998), who found that DAT patients, similar to frontotemporal dementia patients, were more severely impaired in action naming than in object naming. All these studies suggest that DAT subjects naming performance is compromised to a different extent across different semantic categories. These findings may have important implications for theories concerning the underlying mechanisms and anatomical substrates of semantic memory impairment in DAT.

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The need for caution when interpreting such category-specific results also has been raised by some investigators. In studying the methodological problems of confrontation naming tasks, it has been suggested that differences in such factors as lexical frequency, visual complexity, and familiarity among picture samples from different categories may have resulted in spurious category-specific findings (Funnell & Sheridan, 1992; Stewart, Parkin, & Hunkin, 1992; Tippett, Grossman, & Farah, 1996). For example, Tippett et al. (1996) reexamined 14 DAT patients using the stimulus sets previously used in the study by Silveri et al. (1991) and demonstrated a similar category-specific deficit for biological entities in DAT; however, when they used another stimulus set that was matched for word frequency, visual complexity, and familiarity, the finding of category-specific deficit disappeared in the same subjects. Clearly, the choice of stimulus sets can have a profound effect in a study. Recent studies have generally taken into consideration these confounding variables, most often by using ratings derived from the study of Snodgrass and Vanderwart (1980). Although it is convenient to use these standardized norms, we question whether they are applicable to studies of DAT because patients are older and generally less educated than the people from whom the norms have been obtained. Even when particular stimulus factors are matched across categories, it is still uncertain whether the stimulus sets are in fact of equal difficulty when presented to a particular group of subjects in a study. A preferable method is to determine if control subjects perform equivalently in the stimulus sets. In fact, matched control subjects have been included in many naming studies (Cappa et al., 1998; Robinson et al., 1996), but their performances often approach ceiling on all stimulus sets, thereby obscuring any possible differences. As such, it remains unclear whether one category set is relatively more difficult than the other even for normal subjects.

In addition to the methodological problems outlined above, studies of verb knowledge or action naming also have been problematic. *Action,* by definition, refers to the process of doing. In the studies by Cappa et al. (1998) and Robinson et al. (1996), actions were depicted by using static images that were either simple line drawings from the Action Naming Test (Obler & Albert, 1982) or realistic pictures. These static images, however, are only partial or incomplete representations of the actions; each image is only a frozen moment of the entire process of action across time, because the process of action cannot be depicted in a single snapshot. It is almost analogous to supplying degraded or incomplete stimuli in an object naming test by omitting parts or components of the objects. Moreover, in many of the action stimuli used in these studies, there were depictions of objects, the identification of which is often critical to naming the action. For example, to represent the action of sailing, a still sailboat floating on water is depicted in the Action Naming Test. Instead of asking, "Name this action," it seems that the more appropriate question would be "Identify this object first and then tell me which action is associated with it." In other words, the line drawings of the Action Naming Test seem to be a problematic way of depicting action concepts.

In summary, a number of methodological problems may have weakened the results of previous naming studies in DAT. In effect, the status of category effects on picture naming needs to be clarified using more appropriate testing stimuli. Only after solid empirical data are obtained can we proceed to investigate possible mechanisms underlying these category effects. Therefore, the first objective of the present study was to determine if DAT subjects, in fact, showed differences in naming performance when given stimuli belonging to different semantic categories. Special attention was given to equating task difficulty across different categories by establishing appropriate norms for stimulus sets that were free of ceiling effects. In addition to using the conventional Action Naming Test, we also created simple computer animations, which resembled human actions more closely, to test for action naming.

If category effects in DAT subjects could be confirmed on the naming task, our second objective was to determine if the same pattern could also be reflected in a different semantic task undertaken by the same DAT patients. The semantic task used was a semantic association judgment test, which probed the same categories of knowledge presented for naming. However, it did not require complex visual processing and lexical–phonological retrieval, two factors that were important only in picture naming. Hence, if selective picture naming impairment in a DAT subject was largely due to one or both of these factors, category deficits in the semantic association judgment test would be unlikely to emerge. In contrast, if the same pattern of deficit was found on both tasks, we would have converging evidence pointing to a semantic memory deficit underlying the selective naming impairment observed in DAT patients.

Method

Subjects

Twenty patients with a diagnosis of probable DAT according to NINCDS-ADRDA criteria (McKhann et al., 1984) were studied. They were mildly or moderately impaired according to clinical evaluation and their Mini-Mental State Examination scores (Folstein, Folstein, & McHugh, 1975), which were at a mean of 22.5 (SD = 3.9). There were 8 men and 12 women who met the following requirements: they were English speaking; their Wide Range Achievement Test (WRAT3; Wilkinson, 1993) scores were greater than 30 (M = 47.2, SD = 6.4), indicating adequate reading ability; their Hachinski scores were less than 4 (Hachinski et al., 1975); they had no clinical evidence of focal brain disease on neurological examination; they had adequate vision and hearing; and they consented and cooperated. The mean age of the group was 80.6 (SD = 5.6) years and the mean education was 11.2 years (SD = 3.3). The average score on the 60-item Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) was 31.5 (SD = 11.1), and all patients were able to perform a picture naming task. Four patients withdrew before the end of the study: Two completed the first task (naming), and the other 2 completed the second task (semantic judgment; see below). Their results on the completed tests were included in the corresponding group analyses. A total of 16 DAT subjects undertook the entire study.

Sixty elderly control subjects from the same local community also participated in the study. All were assessed clinically as being normal without memory complaints. They scored within 1 standard deviation of the age-adjusted means on a battery of neuropsychological tests of memory (Wechsler Memory Scale; Ivnik et al., 1991); language (Boston Naming Test; LaBarge, Edwards, & Knesevich, 1986); and attention (Trail Making; Partington & Leiter, 1949). None had a history of neurological illness or mental decline, and they were normal on neurological examination. They were recruited to establish normative data for the stimulus sets. Their performance in the original stimulus sets allowed us to preselect stimulus sets for patient testing that were matched for difficulty level and for a number of other confounding variables. They were 28 men and 32 women with a mean age of 76.6 years (SD = 6.4) and a mean education of 12.5 years (SD = 3.0). Their average score on the 60-item Boston Naming Test was 53.6 (SD = 6.8). Because of the length of the entire study, it was divided into three sessions, each of which was attended by 40 control subjects. In other words, the 40 control subjects carrying out the naming task were not all identical to the 40 control subjects carrying out the semantic association judgment task. Twenty-four control subjects were able to attend all three sessions. The three sessions involved, respectively, object naming, action naming, and semantic association judgment, as detailed below.

Materials and Procedures for the Naming Task

In the first test session, we presented to the group of elderly subjects (a) more than 350 standardized black and white line drawings, which were either independently created or taken from Snodgrass and Vanderwart (1980); (b) the Boston Naming Test (Kaplan et al., 1983); (c) the Psycholinguistic Assessment of Language Test (Caplan, 1992); and (d) the Action Naming Test (Obler & Albert, 1982). In addition, 30 animations were constructed using Life Forms software (Credo Interactive, Inc., Vancouver, British Columbia, Canada). The animations were in the form of moving line drawings demonstrating different human action sequences. Each animation was first created on the basis of the human model, and the software allowed us to manipulate the orientation and movement of the limbs and torso in subsequent frames of the animation (see Figure 1). If the action was associated with an object, as in the case of tool use, the object was not added to the animation. Emphasis was put on the overall motion and gesture of the human figure. The resulting motion sequences were displayed on the screen of a Macintosh G3 portable computer for confrontation naming in the second test session.

For each picture or animation, control subjects were asked to give the verbal label of the object or the action and to provide a familiarity and complexity rating. *Familiarity* was defined as the degree to which you come in contact with or think about the object or action on a scale ranging from 1 (*unfamiliar*) to 5 (*very familiar*). *Complexity* was defined as the amount of detail or intricacy of line in the object or action the way it was presented and was rated on a scale ranging from 1 (*least complex*) to 5 (*most complex*). Although similar ratings for many of our line drawings were previously published (Snodgrass & Vanderwart, 1980), we found them inappropriate for the present study because they were collected from younger and more educated individuals. Moreover, the social and cultural backgrounds of our subjects might have affected "the degree to which you come in contact with the object" with regard to our definition of familiarity.

From the control subjects, we obtained a list of acceptable alternate responses for the depicted items. We then selected 45 pictures of biological items and 45 pictures of nonbiological items for object naming, as well as 17 static pictures and 17 animations for action naming (see Table 1), so that the four sets were all matched for accuracy, word frequency (Francis & Kučera, 1986), familiarity, and complexity (see Table 2). Note that the average

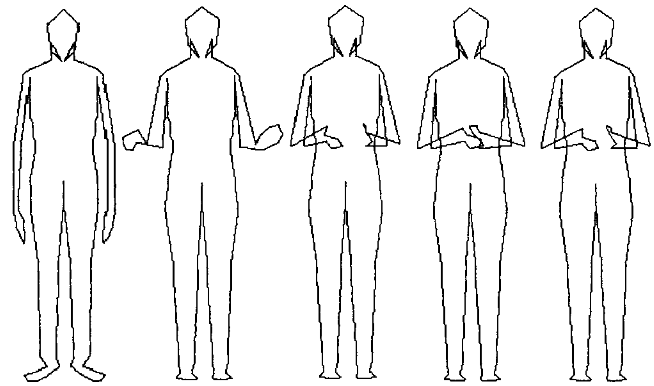

Figure 1. Sequential snapshots of an animation clip representing the action of clapping. The original animation sequence lasts for 5 s, from which five frozen moments during one cycle of clapping are depicted in the diagram. Starting from the human model on the far left, sequential frames (four of which are shown here from left to right) were created by Life Forms Software (Credo Interactive, Inc., Vancouver, British Columbia, Canada).

accuracy score from control subjects was about 80% in each set, thereby avoiding any ceiling effects. This selection process also reduced the total number of pictures to be named, and the influence of fatigue was therefore minimized.

The matched stimulus sets were presented to the DAT patients for confrontation naming. The subjects were under no time pressure when performing the task. Their responses were recorded and scored as either correct or incorrect according to the list of acceptable responses obtained previously from the control group.

Materials and Procedures for the Semantic Task

The semantic association judgment test was modeled on the written-word version of the Pyramids and Palm Trees Test of semantic association (Howard & Patterson, 1992). For each question in the test, subjects were asked to indicate which of the two given words was more similar to a target word (e.g., *lamb: goat, sheep*). In the third test session, a Macintosh G3 laptop computer running the Psychlab software (Bub & Gum, 1990) was used to display each question as a triad of large words on a white screen. The target word was centered on top, and the two choices (i.e., the correct answer and the semantic distractor) were displayed randomly on the lower corner of the screen, one on the left and the other on the right. Subjects entered their responses by pressing one of two labeled keys corresponding with either the left or right word. Accuracy and speed were emphasized, and reaction time was recorded by the computer.

The initial test consisted of more than 450 common words drawn from different semantic categories: biological objects, nonbiological objects, action verbs, and abstract nouns. The target word and the choices in each question all belonged to the same semantic category (see Table 3). In the abstract nouns category, we excluded words that could also be used as verbs (e.g., *consent*). In the verbs category, we excluded conceptual or cognitive verbs such as *thinking*. The verbs were presented in the present continuous form (e.g., *running*).

On the basis of the results obtained from our control subject group, we were able to select 18 to 20 questions in each of the six semantic categories, so that we could match the stimulus sets for accuracy, $F(5, 195) = 0.20$, *ns*, and reaction time, $F(5,$

Table 1
Test Stimuli for the Naming Task

Naming task	No. exemplars	Example
Biological objects		
Birds	8	Eagle
Insects	3	Spider
Mammals–fish	16	Monkey
Marine life	8	Lobster
Fruits and vegetables	10	Lettuce
Nonbiological objects		
All-purpose tools	11	Scythe
Carpenter tools	6	Wrench
Kitchen utensils	6	Kettle
Musical instruments	9	Accordion
Playthings	7	Boomerang
Transportation	6	Wagon
Line drawings of actions		
Object based	2	Sailing
Tool use	7	Brushing
Body part movement	3	Shaking hands
Whole-body movement	5	Exercising
Animations		
Tool use	5	Typing
Body part movement	6	Clapping
Whole-body movement	6	Diving

195) = 1.82, *ns*. There were 48 words (16% of total) that were represented as pictures or animation movies in the naming task during the first test session. Questions for which the average score obtained was less than 65% were discarded. Once again, the average accuracy score was set at about 90% in each of the categories to maintain a fair distance from ceiling. The matched stimulus sets were administered to DAT subjects according to the same procedures used for the control group.

We assessed the results from this experiment in terms of both accuracy and reaction time. For the reaction time measures, we assessed each subject's median response latency for each category. These median reaction times were used to generate a group mean for the category.

Results

Naming Task

Raw scores of correct responses in each naming test were converted to percentages of correct responses for the purpose of comparison among tests. The percentage accuracy scores of DAT subjects are reported in Table 4. Because different control subject groups participated in the different naming tests, it was not deemed appropriate to carry out a Group × Category analysis of variance (ANOVA). Instead, contrasts between the control and DAT groups were performed on each of the naming tests. DAT subjects were significantly less accurate than control subjects on all four naming tests (all $ps < .0001$, with Bonferroni correction).

We performed within-group analyses to determine whether DAT subjects were differentially impaired on the four naming tests. As recommended by Cohen and Cohen (1983) for data involving proportions as dependent variables, we arcsine transformed the percentage scores before performing an ANOVA. The results revealed that their scores on these tests were in fact significantly different, $F(3, 51) = 27.20$, $p < .001$. Post hoc analysis using Tukey's honestly significant difference (HSD) test demonstrated that they performed worse on naming biological objects than on naming nonbiological objects ($p < .05$). They also performed significantly worse on naming actions depicted by line drawings as compared with animations ($p < .01$). Their performance on naming animations was significantly better than on the other three tests (all $ps < .01$). For the purpose of later discussion with reference to other similar studies, the naming scores of the biological and nonbiological objects were averaged for each DAT subject to provide a measure of object naming performance. Comparing object naming and line-drawing-based action naming performance by the DAT subjects in this study failed to reveal any significant differences, $t(17) = 0.11$, *ns*. When the DAT group was divided into two groups of opposite gender, a Gender × Category ANOVA revealed no significant gender group difference, $F(1, 48) = 3.02$, *ns*, or interaction, $F(3, 48) = 0.41$, *ns*, whereas category effects remained significant, $F(3, 48) = 25.35$, $p < .01$.

Table 3
Test Stimuli in the Semantic Association Judgment Task

Category	Example (target word: correct choice, distractor)
Abstract nouns	Chaos: confusion, trouble
Animals	Leopard: panther, fox
Fruits and vegetables	Lemon: lime, pineapple
Clothing and furniture	Shoe: boot, sock
Tools	Nail: screw, drill
Action verbs	Sailing: boating, driving

Table 2
Category Sets Matched for Difficulty and Confounding Variables

	Biological objects		Nonbiological objects		Line drawings of actions		Animations		Category comparison	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*(3, 120)	*p*
Controls' accuracy	81	12	81	12	81	7	80	13	0.05	.98
Familiarity	4.20	0.45	4.32	0.47	4.18	0.45	4.46	0.31	1.70	.17
Complexity	2.14	0.38	2.11	0.62	1.79	0.16	2.16	0.56	2.47	.06
Lexical frequency	7.5	11.8	8.8	15.7	11.2	20.8	12.1	15.7	0.49	.69

Note. Accuracy is in percentage of pictures named correctly. Familiarity and complexity values were rated on a 1-to-5 scale. Lexical frequency values per million were derived from Francis and Kučera (1986).

Table 4
Naming Performance by Control and DAT Subjects

	% accuracy					
	Control		DAT			
Category	*M*	*SD*	*M*	*SD*	*t*(56)	*p*
Biological objects	81	16	31	16	10.9	< .001
Nonbiological objects	81	15	41	15	9.4	< .001
Line drawings of actions	80	15	36	20	9.2	< .001
Animations	80	10	59	15	6.2	< .001

Note. DAT = dementia of the Alzheimer's type. See text for details of within-group comparisons.

Semantic Association Judgment Task

The accuracy scores of the DAT subjects in the semantic judgment task are summarized in Table 5. Because the means of the two biological subcategories were almost identical, they were combined into an average for a single biological category for subsequent analyses. The same procedure was applied to the two nonbiological subcategories. A Group (control, DAT) × Category (abstract nouns, biological objects, nonbiological objects, action verbs) ANOVA demonstrated significant main effects for group, $F(1, 56) = 67.1$, $p < .001$, and for category, $F(3, 56) = 12.6$, $p < .001$. The Group × Category interaction was also significant, $F(3, 56) = 11.2$, $p < .001$. Tests of simple effects revealed that DAT subjects were significantly more impaired than control subjects on the semantic association judgment task in all four categories (all *ps* < .01).

We performed within-group analyses on the accuracy data to determine whether DAT subjects were differentially impaired in the four semantic categories tested. Test of simple effects revealed that their scores in these categories were significantly different ($p < .01$). Post hoc analysis using Tukey's HSD test demonstrated that they were less accurate with biological objects than with nonbiological objects ($p < .01$) and with action verbs ($p < .05$). They were also less accurate with abstract nouns than with nonbiological objects ($p < .01$) and with action verbs ($p < .05$). There was no significant difference between abstract nouns and biological objects nor between nonbiological objects and action verbs. Again, a Gender × Category ANOVA in DAT revealed no gender difference, $F(1, 48) = 0.30$, *ns,* or interaction, $F(3, 48) = 1.51$, *ns,* whereas category effects remained significant, $F(3, 48) = 11.31$, $p < .01$.

Because the control and DAT groups differed considerably with respect to variances in reaction time results (Table 5), we conducted separate Mann–Whitney *U* tests for the categories, to examine any differences between groups. The results demonstrated that DAT subjects were significantly slower than control subjects in all categories (all *ps* < .001). Because the DAT subjects were significantly slower in carrying out the task, the reaction time scores were subjected to *z*-score transformations before we performed an ANOVA, as recommended by Faust, Balota, Spieler, and Ferraro (1999). A Group (control, DAT) × Category (abstract nouns, biological objects, nonbiological objects, action verbs) ANOVA did not show any significant main effect for group, $F(1, 56) = 0.20$, *ns,* or for category, $F(3, 56) = 2.45$, *ns.* The Group × Category interaction was also not significant, $F(3, 56) = 1.39$, *ns.*

Overall Analysis

We compared performance accuracy for the two tasks by using Pearson product–moment correlation coefficients. Using the categories of biological and nonbiological objects for both the naming and semantic judgment tasks, we found that the Pearson correlation between accuracy scores for both tasks was .727 ($p < .005$). In a subanalysis using only the 48 overlapping items in both tasks, the Pearson corre-

Table 5
Performance of Control and DAT Subjects in the Semantic Association Judgment Task

	% accuracy				Reaction time (ms)			
	Control		DAT		Control		DAT	
Category	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Abstract nouns	91	11	67	14	2,880	1,132	7,929	5,238
Animals	91	8	68	14	2,882	1,067	8,799	5,424
Fruits and vegetables	90	6	67	15	2,814	1,029	8,992	5,651
Clothing and furniture	91	8	80	15	2,653	907	8,614	7,020
Tools	90	7	78	15	2,915	909	8,135	6,204
Action verbs	91	8	79	13	2,718	972	7,588	6,148

Note. DAT = dementia of the Alzheimer's type. See text for details of statistical comparisons.

lation between accuracy scores for the two tasks was .546 ($p < .05$) indicating a high degree of correlation.

We also examined the relative accuracy in individual DAT subjects on both the naming task and the semantic association judgment task. We found that 15 of 18 (83%) DAT subjects were less accurate in naming biological objects than nonbiological objects and 17 of 18 (94%) subjects were also less accurate in semantic association judgment of biological objects than of nonbiological objects. Among the 16 DAT subjects who completed both tasks, a consistent biological–nonbiological difference in favor of the nonbiological category on both tasks was noted in 13 (81%) subjects. Similarly, individual cases showed that 17 of 18 (94%) DAT subjects had higher scores for naming animations than for naming biological objects and that 16 of 18 (89%) subjects had better scores for the action verb than for the biological object category on the semantic association judgment task. Again, there was a high degree of agreement between the two tasks, where 15 of 16 (94%) DAT subjects performed better with the verb than with the biological category on both tasks.

Discussion

The first objective of this study was to determine if performance on picture naming would vary reliably in a category-related manner in DAT subjects. Similar to well-controlled studies conducted in other brain-damaged patients (Farah, Meyer, & McMullen, 1996; Gainotti & Silveri, 1996), our results demonstrated that category effects on picture naming in DAT subjects were not simply spurious findings that could be attributable to confounding factors such as word frequency, visual complexity, or familiarity. We observed differences in the performance of DAT subjects by using category stimulus sets for which a large number of normal elderly control subjects performed equivalently at 80% (i.e., no ceiling effect) in each category. With such a special control for general purpose factors and a lack of ceiling effect in the category sets, the differences in naming performance found in our study most likely reflect genuine category effects.

In the present study, DAT subjects showed a disproportionate naming deficit for biological objects relative to their own naming deficit for nonbiological objects, and this was present in both men and women. Although this finding of a dissociation in object naming was in keeping with most studies (Daum et al., 1996; Mauri et al., 1994; Silveri et al., 1991), it contrasted most notably with the study of Tippett et al. (1996), who found no significant category differences in the picture naming performance of DAT subjects. The main limitation in their study was that the performance of age-matched control subjects on the category sets was unknown. In fact, they had no control subjects in their study (neither did the study of Funnell & Sheridan, 1992, from which the stimulus sets were taken). Therefore, they were careful to point out that their stimuli set might have created a bias toward nonbiological objects, offsetting any possible category differences.

Our results on the two action naming tests also addressed controversies in previous studies. The DAT subjects in our study did not show a disproportionate deficit in naming actions; in fact, when presented with animations, their naming performance was significantly better than the other semantic categories we tested. This was not an unexpected finding because our initial hypothesis was that the apparent deficit in action naming reported in previous studies was due largely to the nature of testing stimuli. The use of static images in those studies ignored the time dimension that is essential in the complete depiction of action concepts. Moreover, to decipher such static images, subjects often must infer the action by recognizing the associated object (e.g., to say "skating" after recognizing a pair of skates worn by a human figure). It was therefore not surprising to see a significant improvement (22% increase) in DAT subjects' naming performance when they were shown animations instead of static images.

Inspection of our data, however, also revealed that our DAT subjects did not perform worse in naming static pictures of actions than in naming objects (average of biological and nonbiological objects). In other words, even by using the same tests as in previous studies (Cappa et al., 1998; Robinson et al., 1996), we failed to demonstrate a disproportional deficit in action naming than in object naming in DAT. On the other hand, a recent study by Williamson, Adair, Raymer, and Heilman (1998) reported the opposite pattern of dissociation: DAT subjects performed significantly worse on the Boston Naming Test than on the Action Naming Test. It seems that even with similar testing paradigms, all these studies can yield either no category difference or differences in either direction. These contrasting results might have risen from the use of different sets of object naming stimuli. Most notable in the sets used by Cappa et al. (1998) and Robinson et al. (1996) is the low number of common biological items (animals, fruits, and vegetables). As shown in the present study, DAT subjects' naming performance for these biological objects was compromised to a significantly larger extent than when naming other objects, and the number of biological objects in a stimulus set may critically influence the overall object-naming performance. Therefore, by combining the effects of poor depictions of actions (which decreased action naming performance) and oversampling of nonbiological objects (which in turn raised object naming performance), an apparent dissociation between object naming and action naming in DAT in favor of objects might have emerged in the studies by Cappa et al. and Robinson et al. The performance of control subjects could have helped clarify this point, but there was a ceiling effect in both of those studies, so that it was not possible to discern whether their action naming tests were more difficult to begin with. Nonetheless, regardless of how object naming was tested and compared, our results from the action and animation naming tests, with those from the study of Williamson et al. (1998), argue strongly against the presence of a disproportionate action naming deficit in DAT.

Note that the category-related effects observed in DAT subjects, although significant, were not as strong as those seen in other brain-damaged patients (Pietrini et al., 1988; Warrington & Shallice, 1984). Differences between biological and nonbiological categories were about 10% to 30% in accuracy, as reported in most DAT studies (Daum et al., 1996; Mauri et al., 1994; Silveri et al., 1991). We prefer not to use the term *category-specific deficit* in DAT because these effects are relatively small and they are not specific. In fact, none of the categories we tested were spared in DAT, compared with normal controls' level of naming performance. What then could contribute to these category-related effects? In our second experiment, we examined the pattern of semantic memory impairment in DAT subjects, and the results revealed a pattern consistent with the subjects' performances in the naming task. Specifically, in the semantic association judgment task, our DAT subjects performed significantly worse for biological objects than for nonbiological objects and action verbs; moreover, the DAT subjects also did significantly better on action verbs than on biological objects. The category effects were reflected only in accuracy, with all categories showing equivalent reaction time slowing. In addition, there was a good correspondence between the two semantic tasks on an individual basis. There was a high degree of correlation between the accuracy of subjects on the two tasks, again underlining the conclusion that impairment in both tasks was related to a semantic memory deficit. In summary, a similar pattern of impairment in DAT emerged from a semantic task that did not require explicit visuoperceptual processing or lexical–phonological retrieval. The only processing stage at which the naming task and the semantic association judgment task intersected was semantic memory access and retrieval. Hence, converging evidence from the two semantic memory tasks in the present study provides support for a category-related semantic memory disturbance underlying the pattern of anomia in DAT.

There has been considerable controversy regarding the underlying mechanism of category-selective semantic memory deficit in DAT. In particular, two competing general classes of hypotheses have been proposed by different investigators. In the first account, the importance of different brain regions in instantiating category distinctions is emphasized (reviewed by Gainotti, Silveri, Daniele, and Giustolisi, 1995). Specifically, on the basis of studies of focal brain-damaged patients (Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Warrington & Shallice, 1984), the temporal regions are thought to be important for the representation of information crucial for the naming of biological objects, and the frontoparietal regions are relatively more important for representing information essential for the naming of nonbiological objects and actions. According to neuropathological findings in DAT (Braak & Braak, 1991), temporal regions are the most severely attacked early in the course of the disease, whereas frontoparietal regions are affected, but to a lesser extent. In this formulation, therefore, mild–moderate DAT subjects are expected to have an exaggerated naming deficit for biological objects. In contrast, the naming of nonbiological objects and action verbs would be affected, but to a lesser degree.

Alternate accounts of the category-related semantic memory deficit in DAT de-emphasize the anatomical substrate and postulate that disturbances in a distributed network of semantic knowledge can give rise to the category effects observed (Caramazza, Hillis, & Rapp, 1990; Farah & McClelland, 1991; McRae, de Sa, & Seidenberg, 1997; Small, Hart, Nguyen, & Gordon, 1995). These network accounts have taken several forms and have been implemented to varying degrees in computer simulations of semantic disintegration. One account (Devlin, Gonnerman, Andersen, & Seidenberg, 1998) stresses the relevance of intercorrelated features and distinguishing features supporting concept nodes in a semantic network and the contrasting manner in which they are crucial across biological and nonbiological categories affected throughout the course of DAT. It is proposed that representation of biological objects is based on collateral support of intercorrelated features, with limited distinguishing features. With the progression of DAT, damage to the few distinguishing features and the correlation structure would then yield exaggerated deficits for the biological category. A similar degree of damage would be less catastrophic for the nonbiological category, in which the representation of exemplars depends primarily on the abundant distinguishing features.

A separate network account of semantic disintegration emphasizes the notion of semantic and perceptual densities of differing categories (Dixon, Bub, & Arguin, 1997; Dixon, Bub, Chertkow, & Arguin, 1999). Nonbiological categories have much less overlap among their item concepts than do biological categories. As disintegration of the network occurs (likened by McClelland, 2000, to adding noise to the system), the denser concept neighborhoods will be more likely to demonstrate anomia and semantic impairment than the less dense neighborhoods. Our data are, in fact, compatible with both classes of explanation and do not serve to adjudicate between them with regard to object naming. Our data, however, represent a strong challenge to any claim that the category effects are simply spurious or epiphenomenal.

Of particular interest is that DAT subjects were also impaired in the semantic association judgment task for abstract nouns to a degree equivalent to biological object. This is the first such report in DAT to our knowledge. Within this framework of a distributed semantic network, abstract concepts can be thought of as being similar to biological concepts in that they have many intercorrelations (i.e., synonyms of similar meanings) and few salient distinctive definitions. They would therefore be similarly vulnerable to degradation in DAT, as demonstrated in this study. Conversely, action concepts can be thought of as being similar to nonbiological concepts because actions generally involve few overlapping motions but numerous distinctive trajectories through space and time, and the same degree of damage in DAT might therefore have less dire consequences. These analogous comparisons are admittedly conjectural and require empirical support from further studies.

The present study did not allow us to discern which account put forward to explain semantic category specificity in DAT would best explain the category-related semantic deficits observed. Future investigations should involve studies extending into a broader range of semantic categories. Additionally, longitudinal studies of patients, as well as neuroimaging studies of these patients, may provide further insight into the basis for the pattern of semantic memory disturbances in DAT. Nonetheless, our study presents important data that clarify the relationship between deficits in different categories of knowledge in DAT. We found solid evidence for the presence of category differences in the naming performance of DAT subjects, and these differences were due not to impairment of visuoperceptual or lexical–phonological deficits but rather to the underlying semantic-memory impairment in DAT.

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