

# Object identification deficits in dementia of the Alzheimer type: Combined effects of semantic and visual proximity

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## Abstract

Identification deficits in dementia of the Alzheimer Type (DAT) often target specific classes of objects, sparing others. Using line drawings to uncover the etiology of such category-specific deficits may be untenable because the underlying shape primitives used to differentiate one line drawing from another are unspecified, and object form is yoked to object meaning. We used computer generated stimuli with empirically specifiable properties in a paradigm that decoupled form and meaning. In Experiment 1 visually similar or distinct blobs were paired with semantically close or disparate labels, and participants attempted to learn these pairings. By having the same blobs stand for semantically close and disparate objects and looking at shape–label confusion rates for each type of set, form and meaning were independently assessed. Overall, visual similarity of shapes and semantic similarity of labels each exacerbated object confusions. For controls, the effects were small but significant. For DAT patients more substantial visual and semantic proximity effects were obtained. Experiment 2 demonstrated that even small changes in semantic proximity could effect significant changes in DAT task performance. Labeling 3 blobs with “lion,” “tiger,” and “leopard” significantly elevated DAT confusion rates compared to exactly the same blobs labeled with “lion,” “tiger,” and “zebra.” In conclusion both visual similarity *and* semantic proximity contributed to the identification errors of DAT patients. (*JINS*, 1999, 5, 330–345.)

**Keywords:** Alzheimer’s object identification deficits, Semantic proximity

## INTRODUCTION

In addition to problems remembering recent events, patients with dementia of the Alzheimer type (DAT) often have trouble identifying common objects. Such identification difficulties reflect one of the observable cognitive deficits diagnostic of DAT (Cahn et al., 1997; McKhann et al., 1984) and may provide a basis for early detection (Guterman & Eisdorfer, 1989).

Identification deficits may be attributable to disruptions at different levels of the object identification process. Patients may be unable to perceive the form of objects adequately and hence be unable to identify them. Others may

perceive object form, but be unable to correctly map this form to the appropriate semantics. Others may be able to perceive form, map it to semantics, but be unable to name an object because they cannot access the correct label. Thus, if a patient fails to name an object, little can be said about which level in the object identification sequence has gone awry. In describing previous DAT studies of object processing, therefore, we will use the general term identification deficits rather than “perceptual,” “form-to-meaning mapping,” or “naming” deficits.

## CATEGORY SPECIFIC IDENTIFICATION DEFICITS IN DAT

Most studies using groups of DAT patients have shown that the severity of identification deficits depends on the semantic category to which the tested objects belong. Biological

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objects like plants, animals, and fruits and vegetables appear to be more difficult for DAT patients to name than man-made objects like tools and furniture. Silveri et al. (1991), for example, asked DAT patients to name colored pictures of biological (flowers, fruits, and animals) or nonbiological objects (toys, clothing, vehicles, kitchen items, and furniture). Patients made significantly more errors naming biological, relative to nonbiological objects. These authors proposed that the semantics of biological objects are stored in temporal lobes while the semantics of artifacts are stored in frontoparietal areas. Thus, for these authors, patients show category-specific identification deficits because DAT preferentially attacks the temporal lobes.

Mazzoni et al. (1991) compared 10 DAT patients to 10 vascular dementia patients and 10 control observers across a number of paradigms. Comparisons were made between performance with living (animals, plants, fruits, and food-stuffs) and nonliving entities. Relative to the two control groups, "Alzheimer's patients show a clear and consistent dissociation between living and nonliving things: their ability to define, name and comprehend living stimuli is inferior to that for inanimate ones" (Mazzoni et al., 1991, p. 79). Drawing upon explanations first postulated by Warrington and Shallice (1984) these authors suggested that the identification of living things is disrupted because of damage to a specific component of semantics—that devoted to the processing of visual features. Nonliving things can still be identified because their differentiation relies on a different component of semantics—that devoted to the processing of object function.

Montanes et al. (1995) used standardized black-and-white line drawings (Snodgrass & Vanderwart, 1980) to test DAT confrontation naming performance. These authors investigated biological *versus* nonbiological category membership as well as the visual complexity of line drawings. Patients demonstrated significantly poorer performance for naming biological relative to nonbiological objects irrespective of whether drawings were simple or complex. Subsequent experiments using unstandardized color pictures, however, failed to uncover deficits adhering to the biological–nonbiological distinction. Montanes et al. (1995) argued that in DAT, color plays a crucial role in disambiguating certain living and nonliving things, but conceded that different results might have been obtained had different exemplars, or different categories been used.

Gainotti et al. (1996) compared 16 DAT to 11 healthy control observers on their naming of line drawings of living and nonliving stimuli that were matched in terms of word frequency and stimulus complexity. DAT patients' performance with living things was poorer than with inanimate objects. The authors noted however, that familiarity of the line drawings was not equated and that DAT patients may have performed more poorly with the living things because they were not as familiar as the drawings of the inanimate objects that were tested.

Daum et al. (1996) compared the performance of 8 DAT patients to 8 vascular dementia patients and 8 control ob-

servers on a confrontation naming task with and without the provision of phonemic cuing. The living, and nonliving entities were carefully matched in terms of picture familiarity, picture complexity, and name frequency. Contrary to Gainotti et al.'s justifiable concerns about object familiarity, DAT patients' performance was still significantly poorer for living things for both cued and uncued naming.

Not all group studies of DAT have shown category specific deficits. Hodges et al. (1992) compared DAT naming performance for living things (land animals, sea creatures, and birds) to naming of man-made objects (household items, vehicles, and musical instruments). Although performance was significantly poorer than controls, and poorer for items with lower word frequencies, DAT patients were equally impaired for naming living and nonliving items.

Tippet et al. (1996) demonstrated that category-specific deficits emerged only when using the stimuli of Silveri et al. (1991), but not when the same patients were tested using the more carefully matched stimuli of Funnel and Sheridan (1992). These authors proposed that at least for DAT patients, the category-specific identification deficits shown by Silveri et al. were likely the result of imperfect matches between sets of living and nonliving stimuli on frequency, familiarity, and visual complexity.

Given that Daum et al. (1996) found living and nonliving performance differences with stimulus sets that were carefully matched on these variables, one may have to look elsewhere to explain why some studies show category-specific deficits in DAT and others do not. One possibility may involve which living, and which nonliving, categories were sampled. A clue comes from investigations of category-specific deficits among herpes encephalitis patients. These studies reveal a number of crucial exceptions to the living *versus* nonliving distinction. Patients who typically have problems identifying biological objects but not man-made objects often have few problems identifying body parts (biological objects) but have great difficulty identifying musical instruments, which are obviously man-made (Damasio, 1990; Gainotti & Silveri, 1996; Warrington & Shallice, 1984).

In the DAT studies reviewed above, those studies that found differences between confrontation naming of living and nonliving objects avoided these problematic categories (Daum et al., 1996; Mazzoni et al., 1991; Silveri et al., 1991) while studies that failed to find biological *versus* nonbiological confrontation naming differences extensively sampled these categories (Hodges et al., 1992; Tippet et al., 1996).

The importance of these exception categories cannot be underestimated. Although body parts warrant a special status as objects because they are an intrinsic part of our body image, the same is not true for musical instruments. This crucial exception category poses a serious problem for those who believe that what is spared and impaired by brain damage follows the biological–nonbiological distinction.

A theory that may account both for patients' problems with biological objects, and musical instruments, was proposed by Humphreys et al. (1988). They suggested that

identification problems stem from an interaction between structural similarity and semantic proximity where brain damage causes identification problems for sets of objects whose members are both visually similar and semantically close. Biological objects are preferentially impaired because birds, insects, trees, and animals form groups of structurally overlapping and semantically similar objects. Importantly, nonbiological objects like cars, gemstones, and musical instruments (e.g., banjo, guitar, violin) also pose problems for the same reason. Man-made objects such as tools and furniture, on the other hand, tend to be visually and semantically more distinct. That is, a saw and hammer look quite dissimilar and are used for different purposes. Thus for Humphreys et al., identification problems involve a failure to disambiguate a given exemplar from visual and semantic neighbors within the same category.

The approach used in all of these studies, however, suffers from a basic shortcoming that pervades almost all investigations of object identification: the fundamental inability to specify, at the level of structure, how the actual forms of the tested objects differ from one another. Focusing on DAT research, each of the previously described group studies used line drawings or colored pictures of objects to investigate object identification. Although standardized pictures are beneficial for matching stimulus sets on complexity, frequency, and familiarity, with line drawings one still has no way of knowing exactly how the exemplars making up the living and the nonliving categories differed from one another in the most basic visual terms. That is, even for simple pictures, we still cannot specify the underlying visual principles that allow people to differentiate a line drawing of a cow from that of a dog. Hence, exactly what mechanisms, if any, fail at the level of structural shape processing in DAT patients remains a matter of conjecture.

The core of the problem involves exemplar similarity. Although one may surmise that patients may have problems discriminating between items that are visually similar (e.g., Damasio, 1990) it is difficult to know exactly what constitutes visual similarity especially in complex line drawings. Although ratings of similarity can be gathered from normal participants, the principles that healthy observers use to base their judgments may not be of the sort that are crucial to category-specific identification deficits. Indeed we have shown that a patient with category-specific identification deficits was actually *better* at identifying a set of objects that normals rated as being more visually similar than he was at identifying a set of objects with lower visual similarity ratings (Dixon et al., 1997). The point is, at least for certain types of stimuli, normals' ratings of visual similarity are not always the best means of predicting which objects will pose identification problems for patients with category-specific deficits.

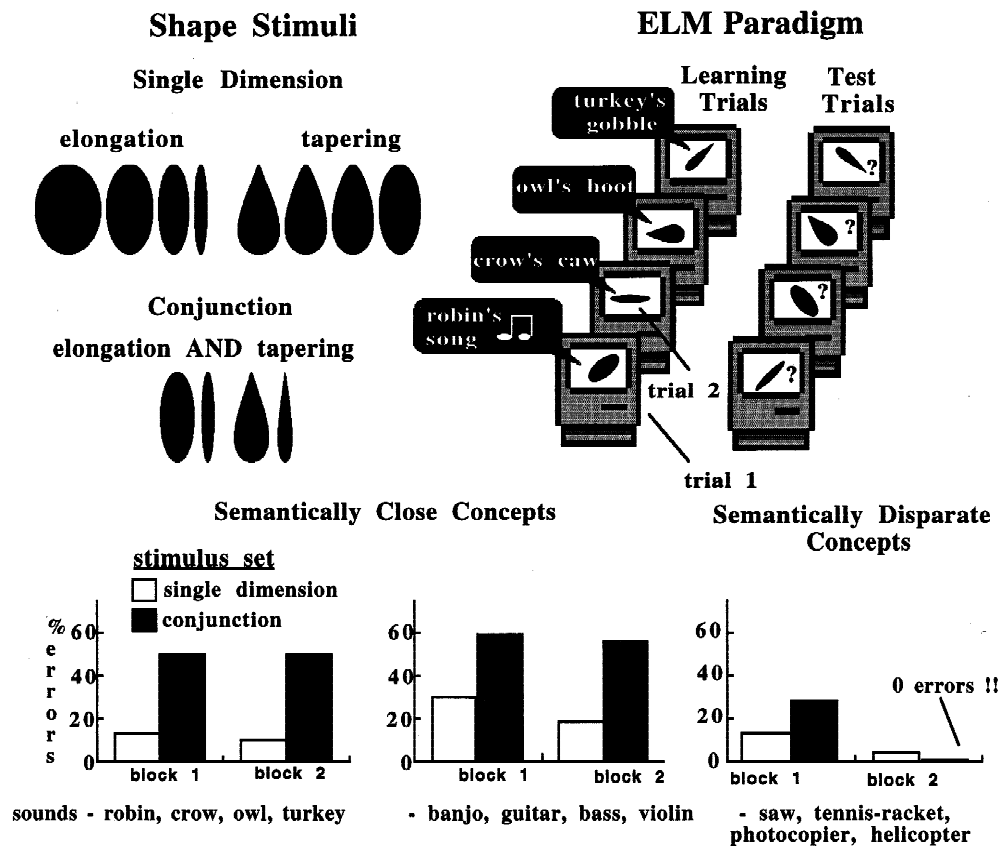
A second and arguably more important drawback involves the relation of exemplar similarity to object form and object meaning. In line drawings, the form of the portrayed object is inextricably yoked to the semantics of the object. That is, without using words, the only way of visually evok-

ing the semantics of "crow," "pigeon," and "sparrow," has been to show three objects each with a head, body, wings, and a tail all of slightly different proportions. If patients misidentify these exemplars, but correctly identify depictions of a "toad," a "donkey," and a "seal," one can never know whether patients' problems with birds are because they are too similar in meaning, or too similar in form. In order to disambiguate form from meaning, ideally one should hold form constant, and manipulate semantics, and then hold semantics constant and manipulate form. The irrefutable fact remains, however, that in line drawings form is bonded to meaning, thereby precluding their separate evaluation.

Recently, we created a paradigm that circumvents this problem and have used it to uncover the etiology of the category-specific identification deficits experienced by the temporal lobe stroke patient E.L.M. This patient has identification problems primarily with biological objects (fruits, vegetables, animals, insects, and birds) but also cannot identify stringed musical instruments (banjo, guitar, violin). Conversely, he identifies other artifacts like tools and furniture quickly and easily. The paradigm used to uncover the source of E.L.M.'s category-specific deficits employed simple computer-generated blobs with well-defined underlying shape dimensions. Shape dimensions are properties like curvature, thickness and tapering. By manipulating values on these dimensions, sets of blobs were generated that shared values along single or multiple shape dimensions. Examples of these single dimension and conjunction shape sets are shown in Figure 1.

Arguin et al. (1996b) showed that E.L.M. was relatively good at identifying blobs when they could be discriminated by attending to any single visual dimension (e.g., thickness in the single dimension set shown in Figure 1) but was markedly impaired when blobs within a set shared values on multiple visual dimensions (e.g., thickness *and* tapering). Dixon et al. (1997) used the paradigm shown in Figure 1 to demonstrate that these structural impairments interacted with semantics in a remarkable way. On learning trials, each of the shapes comprising either the single dimension or the conjunction sets was paired with a familiar sound. On test trials the shapes appeared alone and E.L.M. had to remember the sound with which the shape had been paired.

The sounds paired with shapes were either semantically similar (e.g., sound of a robin, crow, owl), or disparate (e.g., sound of a saw, helicopter, photocopier). For single dimension sets E.L.M. performed equally well for either type of set. For conjunction sets when blobs were paired to semantically close sounds E.L.M.'s shape identification was poor but when the *identical shapes* were paired with semantically disparate sounds E.L.M.'s identification performance, after an initial learning period, was flawless. This finding was replicated using verbal labels as well as digitized sound recordings. Extensive testing with E.L.M. revealed that it did not matter whether labels referred to biological or nonbiological categories; for conjunction sets if the labels were semantically close (e.g., four sports-car labels) performance was poor. If the labels were semantically disparate



**Fig. 1.** The computer generated shape sets, paradigm and results of Dixon et al. (1997). Results are the percentage of test-trial errors for single dimension and conjunction shape sets associated with semantically close and semantically disparate concepts. Each block contains 96 test trials.

(e.g., “wasp,” “lion,” “frog,” and “hummingbird”) his performance was near ceiling. This pattern of increased identification errors for sets of shapes that shared multiple visual features *and* refer to semantically close concepts has since been replicated in another patient with category-specific visual agnosia (Arguin et al., 1996a).

Where this paradigm excels in relation to veridical object identification or confrontation naming is in its ability to decouple object form from object meaning. By having exactly the same shape sets stand for both semantically close and disparate objects one can directly assess the ramifications of semantic proximity on object identification unconfounded by visual proximity. Concurrently, by applying the same labels to visually similar or visually distinct blob sets, one can directly assess the ramifications of visual proximity unconfounded by semantic proximity.

We view E.L.M.’s problem as a consequence of how humans store objects in memory. We find it heuristically useful to view objects as being stored in a multidimensional psychological space whose axes are determined by both visual and semantic attributes. In such a space, sets of objects that have many overlapping attributes will be stored close together, and be more confusable than objects that have few attributes in common. For healthy observers, objects that are stored close together typically pose few identification

problems except for items with a tremendous amount of visual and semantic overlap (e.g., birds such as wren, sparrow, swallow, flicker). For patients like E.L.M., however, brain damage leads to an abnormal propensity to confuse exemplars that are stored even marginally close together in multidimensional space. Thus E.L.M., in addition to having trouble with birds, also has trouble identifying more differentiable exemplars that pose few problems for healthy observers; categories such as common animals, insects, and fruits and vegetables. The reason E.L.M. has category-specific deficits is that exemplars within certain categories like tools and furniture are stored further apart in multidimensional space by virtue of their sharing few semantic and visual attributes. That is, a hammer and a saw look completely different, and are used for very different purposes. Hence, such objects are far less prone to within-category confusions and are more readily nameable.

Although E.L.M. and DAT patients have both been documented as showing category-specific deficits, it must be remembered that they differ in a number of important respects. First, E.L.M.’s cerebrovascular accident caused damage restricted to specific areas of the temporal lobe which left his perception intact but rendered him unable to identify certain objects. Individual DAT patients, on the other hand, can display modular patterns of deficits involving ei-

ther semantics or perceptual deficits (Chertkow & Bub, 1990; Montanes et al., 1995). Secondly, in terms of semantics, E.L.M. has intact encyclopedic knowledge about objects he cannot visually identify. When asked to define “camel,” he can state that it lives in the desert, that people ride on them, and that they have been referred to as “the ship of the desert” (Dixon et al., 1997). DAT patients have preferential impairments in this type of knowledge even for objects which they are able to name (Chertkow et al., 1992; but see Hodges et al., 1996 and Lambon Ralph et al., 1997 for a dissenting view).

Despite such differences between E.L.M. and DAT patients there are crucial points of overlap. Like E.L.M., DAT patients demonstrate preferential identification difficulties for visually similar and semantically similar objects. DAT patients clearly have episodic memory problems for shapes (e.g., the Fuld object memory test: Fuld, 1981; Fuld et al., 1987). E.L.M. also shows problems for delayed recall of pictorial material (Dixon et al., 1997). One of the early stage complaints of DAT patients is an inability to identify familiar faces (Guterman & Eisdorfer, 1989). Like such patients, E.L.M. is profoundly prosopagnosic (Dixon et al., 1998). Finally, anatomical mappings of early DAT brain damage suggests a prevalence of neurofibrillary tangles in the temporal lobes (Brodmann’s areas 20, 21, and 37) along the ventral visual processing stream (Arnold et al., 1991; Bouras et al., 1994; Damasio et al., 1990b); the stream presumed to sustain object identification (Desimone et al., 1984; Gross et al., 1972; Ungerleider & Mishkin, 1982). Like early DAT patients, E.L.M. has bilateral temporal lobe damage in Brodmann’s areas 21 and 37. These constellations of overlapping symptomatology suggest that the combination of visual similarity and semantic proximity of objects that so profoundly affects E.L.M. may also contribute to object identification problems in DAT. If so, the E.L.M. paradigm should be advantageous in showing how semantic and visual proximity each affect object identification in DAT.

Before applying the paradigm directly to patients we took into account a number of relevant factors which could affect DAT’s performance on the E.L.M. paradigm. These were the severity of patients’ episodic memory problems, the possibility of perceptual deficits precluding them from adequately perceiving differences between visually similar blobs, and their proclivity to misidentify objects with low word frequency labels.

To accommodate severe episodic memory problems, we reduced the set size of blobs from four to three and selected patients who showed only mild cognitive deficits. To screen for perceptual deficits severe enough to disrupt blob disambiguation at input, we conducted a matching to sample test using blobs with multiple overlapping visual features (see the visually close set in Figure 2). To maximize the sensitivity to potential object identification problems in DAT we paired blobs only with low-frequency labels.

Taking these factors into account two central hypotheses were postulated. First, for both control participants and DAT patients we predicted that greater numbers of identification



**Fig. 2.** The visually distinct and visually similar computer generated blob sets.

errors would be made when visually similar shapes were associated with semantically close concepts. Second, we predicted that DAT patients would be much more profoundly affected by visual and semantic similarity than healthy controls. Finally, we predicted that whether blobs were mapped to biological or nonbiological concepts would have no bearing on performance.

## METHODS

### Research Participants

Patients with probable DAT as assessed by NINCDS–ADRDA criteria (McKhann et al., 1984) were recruited from the memory clinics of the Douglas Hospital Research Center and the Jewish General Hospital. Patients met the following criteria: English speaking, Hachinski Ischemia Scale (Hachinski et al., 1975) scores of 4 or less; Mini Mental Status Examination (MMSE) scores of less than 27; no evidence of other neurological disease, adequate hearing, cooperative and consenting.

Patients were excluded if they had perceptual problems severe enough to prevent them from passing the matching to sample test; if patients could not perceptually distinguish between simultaneously presented blobs, it was futile to test their memory for blob–label pairs. Twenty-one patients were tested. Of these, 4 failed the matching to sample test, 1 surpassed the MMSE cutoff (MMSE = 28), 4 dropped out prior to completing the study, and 2 failed to adequately comprehend the instructions after numerous practice trials. For 2 individuals, testing was discontinued after two sessions when it became evident that the task was too difficult for them (performance on both sessions was at chance).

After exclusion, 8 DAT participants remained for whom complete data was collected. These patients were compared to 8 healthy, independent living, elderly controls who had no subjective memory complaints. Subjective memory assessments of control participants were validated by their younger relatives. No control participant had a major medical illness or was taking psychoactive medication. Controls were slightly, but not significantly older than DAT participants [ $t(14) = .58$ , n.s.]; mean age for controls = 78.75 (range 65–90,  $SD = 9.03$ ), mean age for DATs = 76.37 (range = 65–85,  $SD = 7.20$ ). Controls had significantly higher MMSE scores than DAT participants [ $t(14) = -8.21$ ,  $p < .001$ ]; mean MMSE for controls = 29 (range = 27–30,  $SD = 1.07$ ), mean for DAT participants = 23.25 (range = 21–26,  $SD = 1.67$ ).

## Apparatus

All experiments were presented using a Macintosh Powerbook (170) computer controlled by psychlab software (Bub & Gum, 1990).

## Stimuli

The six blobs shown in Figure 2 were generated by combining different values of curvature, thickness and tapering. All blobs were 70 mm in height. In the visually distinct set, blobs differed in terms of curvature, asymmetrical tapering, and thickness (width along the horizontal axis); hence there were no shared values on any of the employed shape dimensions. In the visually similar set there were multiple shared dimension values among set members. Blobs A, B, and C were all equally tapered. Blobs B and C were equally curved (1/3 the curvature of Blob A); Blobs A and B were equally thick (30 mm)—twice the width of Blob C (15 mm along the horizontal axis).

## Verbal Labels

Low-frequency labels were paired to blobs. Frequencies (Kucera & Francis, 1967) appear in brackets following label names. Labels referred to either biological objects that were semantically close: “lion” (17) “tiger” (7), “zebra” (1); or semantically distinct: “robin” (2), “donkey” (1), “frog” (1). Likewise, artifacts were either semantically close: “guitar” (19), “violin” (11), “banjo” (2); or distinct: “carriage” (17), “wrench” (0), “kite” (1).

## Procedure

### *Matching to sample*

A lineup consisting of the visually similar triad was presented along with a target blob centered below the lineup. Participants were asked to point to the blob in the lineup that was the same as the target. Eighteen trials were administered (six for each of three possible targets). Shapes within the three lineup positions were varied such that all six possible shape–location combinations were used equally often. Patients were required to obtain a minimum of 17/18 correct trials on this task in order to participate in further testing.

### *Blob label matching—Learning trials*

Blobs were presented one at a time accompanied by a digitized recording of their preassigned label. Blobs were centrally presented while the name was simultaneously played over the computer’s speaker. Each blob remained on-screen for 2,000 ms, followed by a blank screen intertrial interval of 3,000 ms. Six such learning trials were presented (two of each shape–label pairing). Learning trials were presented in pseudorandom order with the proviso that identical shapes never followed one another.

### *Test trials*

After a 500 ms READY prompt and a 500 ms blank interstimulus interval, centrally presented blobs were presented without their labels. Participants attempted to “name” the blob (give the label associated with the blob on learning trials). Naming was not under time pressure. Blobs remained on-screen until an answer (correct or incorrect) was given. Participants were given a printed list of that session’s three possible labels to refer to as needed. All answers including “don’t know” responses were recorded, and participants were encouraged to guess if they were not sure. Six such test trials were presented (two for each shape). A 1,000 ms intertrial interval separated test trials.

This six-learning–six-test trial pattern was repeated until 72 learning and 72 test trials were completed. The relevant data are the number of errors participants made on test trials for the various blob set–label set pairings.

### *Blob–label assignments*

For each patient eight sessions were conducted (4 triads of verbal labels  $\times$  2 triads of blobs). Sessions were conducted on separate days with a minimum delay between sessions of 1 week. For the initial session the visually distinct set was paired to one of the four label triads. Subsequent sessions used shape–label pairings that were preassigned in a pseudorandom fashion with the proviso that neither identical blob sets nor identical labels were used on consecutive sessions.

## RESULTS

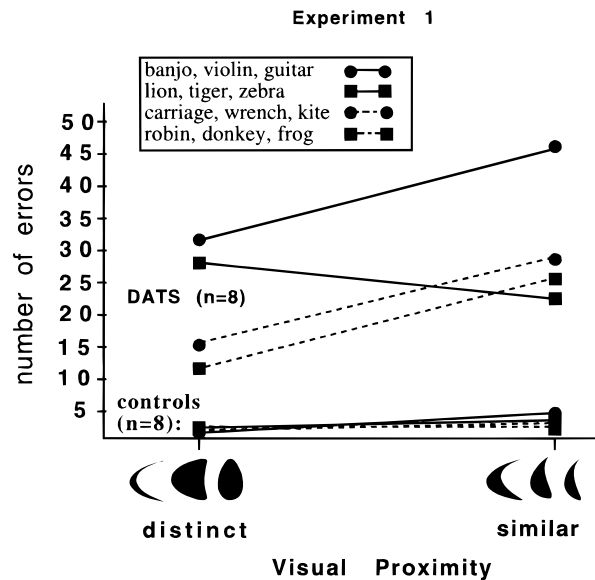
The naming errors of DAT patients and controls are presented in Figure 3.

### **Control Performance**

Healthy, aged, control participants had few problems mapping any type of label to either visually close or distinct blobs with performance being close to ceiling. In order to evaluate whether controls’ confusions conformed to the psychological (visual *and* semantic) similarity of the objects within sets, the control data was analyzed separately from the DAT data in order to obtain the most appropriate error term for the control group. The mean number of confusions made by control observers in this paradigm are depicted in Table 1. An analysis of variance on the control data revealed significant main effects for semantic proximity [ $F(1,7) = 5.61, p = .05$ ], and shape proximity [ $F(1,7) = 9.21, p = .019$ ] in the predicted direction, and, as predicted, no effect of biological category membership [ $F(1,7) = .09, n.s.$ ] nor any higher-order interactions.

### **DAT Performance**

Because a key prediction involving DAT performance was that, relative to controls, DAT patients would be more sus-



**Fig. 3.** Error performance for DAT and normal participants attempting to identify the visually distinct and similar blob sets mapped to semantically close and semantically distinct labels that referred to either nonbiological or biological entities.

ceptible to the effects of visual and semantic similarity, the control and DAT data were analyzed together.

A four-way mixed model analysis of variance was used to analyze the error data on the blob–label identification test. Omega squared ( $\omega^2$ ) was used to determine the effect sizes associated with significant effects. Groups (DAT vs. control) comprised the between factor, and visual proximity (similar vs. distinct), semantic proximity (close vs. far), and biological category membership (biological, man-made) were the *within* factors. This analysis disclosed significant main effects for group [ $F(1, 14) = 126.02, p < .001, \omega^2 = .508$ ], visual proximity [ $F(1, 14) = 7.95, p = .014, \omega^2 = .020$ ], semantic proximity [ $F(1, 14) = 31.66, p < .001, \omega^2 = .032$ ], and category membership [ $F(1, 14) = 6.72, p = .021, \omega^2 = .013$ ]. In addition there was the predicted Group  $\times$  Semantic interaction [ $F(1, 14) = 24.03, p < .001, \omega^2 = .023$ ] and a Group  $\times$  Category Membership interaction [ $F(1, 14) = 7.51, p = .016, \omega^2 = .015$ ]. The predicted Group  $\times$  Shape Proximity interaction only approached significance [ $F(1, 14) = 3.63, p = .077$ ]. The analysis also revealed a single three-way interaction: Shape Proximity  $\times$  Semantic Proximity  $\times$  Category Membership [ $F(1, 14) = 11.31, p = .005, \omega^2 = .003$ ], and a four-way interaction: Group  $\times$  Shape Proximity  $\times$  Semantic Proximity  $\times$  Category Membership [ $F(1, 14) = 8.91, p = .01, \omega^2 = .002$ ].

Tukey HSD *post-hoc* analyses revealed that the four-way interaction and other main effects and interactions involving biological category membership were attributable to the performance of DAT participants when mapping visually close objects to “lion,” “tiger,” and “zebra”—a set we will refer to in folk biological terms as “African Animals” (most people don’t realize that tigers are not native to Africa). The

atypicality of performance on this set is apparent when the effects of visual proximity, semantic proximity and category membership are each considered independently. For the following summary of these factors, all significant Tukey *post-hoc* analyses had  $p$  values less than .01.

### Visual Proximity

Tukey *post-hoc* analyses revealed that when exactly the same label sets were applied to visually distinct and similar blobs, DAT performance was significantly poorer for visually similar blobs for three out of four relevant comparisons (the three ascending parallel lines in the left panel of Figure 3). For the set of blobs mapped to African Animal labels, this effect of visual proximity was absent (the slight descent in this DAT line in Figure 3 reflects nonsignificant differences between the means of the visually similar and visually distinct blobs mapped to these labels).

### Semantic Proximity

Tukey *post-hoc* analyses revealed that when the same blobs were paired with semantically close (biological or man-made) and semantically disparate labels (biological or man-made), blobs associated with semantically close labels yielded significantly poorer identification than blobs associated with semantically disparate labels for three out of the four relevant comparisons. In Figure 3 these three comparisons can be seen by noting the (approximately equivalent) distances between (1) the circles in the visually distinct condition, (2) the squares in the visually distinct condition, and (3) the circles in the visually similar condition. For the comparison involving the semantically close African Animals and semantically disparate animal set (the squares in the visually close condition), this effect of semantic proximity was absent.

### Biological Category Membership

Tukey *post-hoc* analyses revealed *no* differences between DAT performance using biological *versus* man-made labels for three of the four relevant comparisons. These three effects can be seen in Figure 3 by looking at the close proximity of the two dashed lines, and the close proximity of the African animals and stringed instrument conditions in the visually distinct condition (upper-left circle and square). Contrary to *a priori* predictions, when African Animals were mapped to visually similar blobs, however, identification was significantly better ( $p < .01$ ) than when these same blobs were associated with the three stringed instruments.

Ranking the main effects and interactions in terms of effect sizes (as assessed by  $\omega^2$ ) the grouping variable accounted for over 50% of the total variance in this study. The next largest effect sizes were associated with semantic proximity (3.2% of variance), the group by semantic proximity interaction (2.3% of the total variance) and visual proximity (2.05% of the variance). All other significant

**Table 1.** Mean number of confusions among healthy control observers for visually distinct and close shapes mapped to semantically close and distinct labels from biological and nonbiological categories

Semantic relation	Biological		Nonbiological	
	Visually distinct <i>M</i>	Visually close <i>M</i>	Visually distinct <i>M</i>	Visually close <i>M</i>
Semantically close	2.00	3.13	.75	3.50
Semantically disparate	1.25	1.88	1.00	2.00

effects had relatively trivial effect sizes (less than 2% of total variance).

## DISCUSSION

For seven of the eight data points in Figure 3, patients' performance reflected strong effects of both visual proximity and semantic proximity but no effects of whether an object belonged to a biological or nonbiological category. For example, when DAT patients were presented with sets of visually close blobs paired with semantically close labels of stringed instruments performance was exceedingly poor (over 16 *SDs* poorer than the performance of similarly aged controls).

The most intriguing and unexpected finding, however, was that visually similar blobs associated with semantically close African Animal labels elicited performance akin to that noted for the semantically disparate labels. Word frequency could not account for this finding: Frequencies for this set were almost identical to the three musical instruments which elicited markedly poor DAT performance. Although no *a priori* attempt was made to match these label sets in terms of concept familiarity ratings (Snodgrass & Vanderwart, 1980), the items "lion" (2.0); "tiger" (2.1); and "zebra" (1.6) appear to be equivalent to or in most cases actually *lower* than the other labels used: "carriage" (2.72); "wrench" (2.72); "kite" (2.48); "guitar" (3.58); "violin" (2.68); "frog" (2.48); and "donkey" (1.88); "banjo" and "robin" not available. Since *high* familiarity objects tend to be better identified (Farah & McClelland, 1991; Stewart et al., 1992) it is unlikely that the *low* concept familiarity of this African Animal set accounted for the better than expected DAT performance.

One final possibility concerns an imbalance in the semantic similarity among the three members of the African Animal set. Although undoubtedly, "lion" and "tiger" share a myriad of semantic features, "zebra" may be a semantic outlier relative to the two felines. Support for this contention comes from a study combining cluster analysis and multi-dimensional scaling designed to derive cognitive maps of how DAT patients and normals represented certain animals in memory (Chan et al., 1993). For healthy observers, lion, tiger, and zebra were in the same "wild animal" cluster, but lion and tiger were adjacent points in terms of semantic distance, with zebra being located a substantial distance away

from the felines within this cluster. For DAT participants, not only were zebra and tiger stored far apart in terms of semantic distance, but zebra was stored in a different cluster than the two felines.

Thus, for DAT participants, rather than constituting a triad of equally confusable labels, "lion," "tiger," and "zebra" might actually have constituted a *pair* of highly confusable exemplars and a semantic outlier. If the "zebra" blob was rendered distinct in memory because of its semantic uniqueness, then participants might be less prone to confuse this exemplar with the other exemplars in the triad, thereby reducing the total number of confusions associated with this set as a whole. Furthermore, with the "zebra" blob removed from the triad, patients could accurately disambiguate the "lion" and "tiger" blobs by attending to attribute values on a single visual dimension (e.g., the "lion" blob is thicker than the "tiger" blob), rather than relying on conjunctions of attribute values across multiple dimensions. Our previous research with E.L.M. indicated that such shape set dimensionality had profound influences on identification performance (Dixon et al., 1997).

If this hypothesis is correct, then by going back and re-analyzing which blobs DAT patients confused in this set, one should see greater confusions between the "lion" and "tiger" blobs than between either the "lion" and "zebra" pair or the "zebra" and "tiger" pair. Furthermore, if indeed DAT error rates were reduced by the inclusion of the semantically distinct "zebra" label, then by replacing the "zebra" with a feline label such as "leopard" the confusability of all three exemplars should be equated. That is, pairwise confusions between "lion"–"tiger," "lion"–"leopard," and "tiger"–"leopard" should all be equal and errors on this new set should increase to levels comparable to the errors associated with the three stringed musical instruments. Thus, replacing the African Animal set with the "African Cat" set, would provide a better test of the effects of semantic proximity and biological category membership and on object identification. It was predicted that DAT participants mapping the visually similar blob set to the labels "carriage," "wrench," "kite"; "robin," "donkey," "frog"; "banjo," "guitar," "violin"; and "lion," "tiger," "leopard" would result in error patterns indicative of a strong effect of semantic proximity but no effect of whether labels pertained to biological or man-made objects.



## EXPERIMENT 2

### Research Participants

Seven of the 8 DAT patients were retested on the visually close set using the labels “lion,” “tiger,” and “leopard.” One previously tested participant was unavailable.

### Stimuli

New pairings between the three visually close blobs and the three feline labels were effected such that “lion” and “tiger” were assigned to different blobs than were originally learned in the “lion”–“tiger”–“zebra” pairings. A minimum of three weeks had elapsed between testing of the “lion”–“tiger”–“zebra” triad and the “lion”–“tiger”–“leopard” triad.

### Procedure

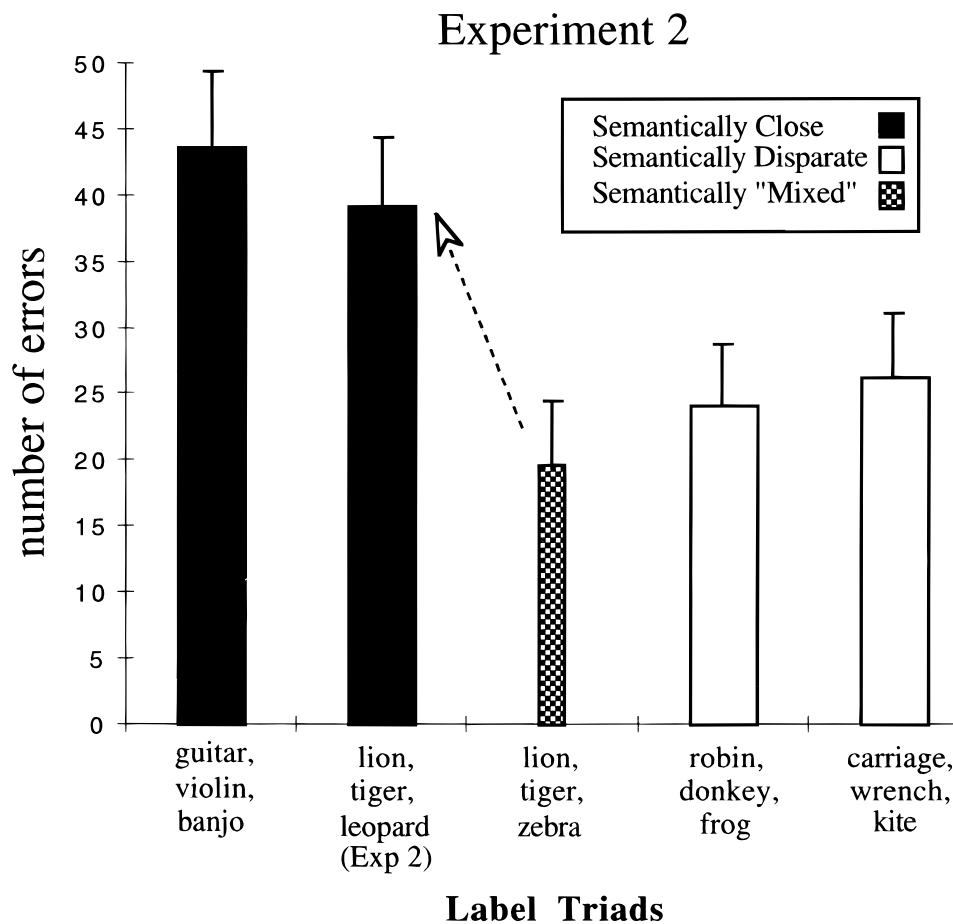
A total of 72 learning and 72 interleaved test trials, identical to Experiment 1, were administered.

## RESULTS

The data are summarized in Figure 4, which depicts the performance of DAT participants mapping visually close shapes to semantically close: stringed musical instrument labels and African cat labels (black bars); and semantically disparate labels: unrelated artifacts and unrelated animals (white bars). For comparison purposes, the checkered bar in Figure 4 represents data from the 7 DAT patients when they mapped visually close objects to “lion,” “tiger,” and “zebra.”

### Comparison of African Animals versus African Cats

A directional, dependent *t* test [ $t(6) = 2.26, p = .034$ , one-tailed] indicated that the 7 DAT patients (those with complete data for Experiments 1 and 2) made significantly more errors for visually close blobs associated with the labels “lion,” “tiger,” and “leopard” ( $M = 39.29, SD = 13.46$ ) than for the same blobs labeled with “lion,” “tiger,” and “zebra” ( $M = 19.71, SD = 12.73$ ). The arrow in Figure 4, points to this marked exacerbation of errors.



**Fig. 4.** Error performance for 7 DAT participants attempting to identify the visually similar blobs mapped to “lion,” “tiger,” and “leopard.” Experiment 1 error performance for these same subjects attempting to name visually similar blobs mapped to “lion,” “tiger,” “zebra”; “guitar,” “violin,” “banjo”; “carriage,” “wrench,” “kite”; and “robin,” “donkey,” “frog” are also presented.

## Confusion Matrices

The 8 DAT subjects participating in Experiment 1 made a total of 205 scorable errors on the visually similar set mapped to the labels “lion,” “tiger,” and “zebra” (“don’t know” errors were excluded). Confusions were allocated into three categories: “lion”–“tiger” confusions (saying “lion” when the correct answer was “tiger” or “tiger” when the correct answer was “lion”); “zebra”–“lion” confusions; and “tiger”–“zebra” confusions. In a balanced set, the expected frequency for the three categories should be 33.33% of total errors (68.33 confusions per category). Table 2 shows that among the observed frequencies for these three categories there was a disproportionately greater number of “lion”–“tiger” errors relative to the other two categories [ $\chi^2(2) = 10.31, p < .01$ ].

The 7 DAT patients participating in Experiment 2 made a total of 259 scorable errors on the visually similar set mapped to the labels “lion,” “tiger,” and “leopard.” Confusions were allocated into three categories: “lion”–“tiger” confusions, “lion”–“leopard” confusions, and “tiger”–“leopard” confusions. Table 2 shows that the observed frequencies for all three categories were similar to, and not statistically different from the expected frequencies [ $\chi^2(2) = 1.59, n.s.$ ].

A  $2 \times 2$ , repeated measures analysis of variance was conducted on DAT patients’ confusions to assess the relationships among semantic proximity (close, disparate) and category membership (biological, man-made) using the new data for the semantically close “lion”–“tiger”–“leopard” triad. Confirming the relationships visually depicted by the black-and-white bars in Figure 4, semantically disparate labels (white bars) yielded significantly fewer errors than semantically close labels [black bars;  $F(1,6) = 11.99, p = .013$ ]. There was neither a main effect for category membership [ $F(1,6) = .47, n.s.$ ], nor an interaction between Semantic Proximity  $\times$  Biological Category Membership [ $F(1,6) = .16, n.s.$ ].

## DISCUSSION

Replacing the label “zebra” with the label “leopard” effected a significant increase in errors for visually close blobs

labeled with three felines, relative to the same blobs labeled using two felines and a zebra. Given the episodic memory problems that are the hallmark of DAT patients, this increase in errors was not likely attributable to interference effects. Furthermore, there was a minimum 28-day separation between the African Animal and African Cat sets. Additionally, randomization of the order of presentation for the various label–set blob–set combinations in Experiment 1, meant that only 1 participant received the African Animal and African Cat sets consecutively (albeit 28 days apart). These factors all argue against interference effects elevating African Cat errors to the levels observed in Experiment 2.

Finally, it is unlikely that the African Cat errors were greater than the African Animal errors because of the passage of time. Because DAT is associated with decreasing functioning over time, and because all participants were tested on the African Cats after the African Animal set, it could be argued that performance was poorer on this set because patients were sicker. Three factors argue against this hypothesis. First, as can be seen in Figure 4, performance on African Cats is ordinarily better than performance on the three stringed instruments whose testing was completed prior to the African Cat set. Second, the delay between testing was relatively brief, ranging from 28 days to just over 8 months. Third, the correlation between this delay and performance decreases on the three-feline set (African Cat errors – African Animal errors) was not significant.

Given the untenability of these hypotheses, it appears that errors on the African Cat set were elevated because replacing “zebra” with “leopard” created a semantically closer set of labels that was more balanced in terms of exemplar confusability than the semantically mixed “lion,” “tiger,” and “zebra” set. The chi-square analyses of this new triad indicated that each exemplar was equally confusable with every other exemplar, and as a whole this three-feline triad elicited significantly more errors than the unbalanced triad comprised of a pair of felines and a herbivore.

The equivalent pairwise confusions in the African Cat set argues against the possibility that the imbalanced confusions in the “lion”–“tiger”–“zebra” set were caused by visual, rather than semantic factors. That is, it is unlikely that

**Table 2.** Total number of confusions for visually close triad members labeled using “lion,” “tiger,” “zebra,” and “lion,” “tiger,” “leopard”

Experiment	“Lion”–“Tiger”	“Lion”–“Zebra”	“Zebra”–“Tiger”	$\chi^2$ value
	Confusions	Confusions	Confusions	
Experiment 1 ( $N = 8$ )	90 (68.33)	58 (68.33)	57 (68.33)	$[\chi^2(2) = 10.31, p < .01]$
Experiment 2 ( $N = 7$ )	“Lion”–“Tiger”	“Lion”–“Leopard”	“Leopard”–“Tiger”	$\chi^2$ (2) = 1.59, n.s.]
	Confusions	Confusions	Confusions	
	81 (86.33)	97 (86.33)	81 (86.33)	

Note. Expected values for confusions are in parentheses.

“lion”–“tiger” blobs were confused more often than blob pairs involving the “zebra” blob simply because these labels were attached to blobs that looked more similar. When labels were semantically equated by using three feline labels, no pair of blobs was any more confusing than any other pair of blobs.

Having a semantically equidistant triad of labels, we were now in a position to better assess the ramifications of the biological *versus* nonbiological category distinction. In Experiment 2, obtaining relatively large (yet equivalent) deficits for performance on visually close blobs mapped to three feline labels and three man-made stringed instrument labels, and much smaller (yet equivalent) deficits for three unrelated animal and three unrelated artifact labels suggests that what is important for object identification in DAT is not whether exemplars are man-made or biological, but rather, whether objects within a set are semantically proximate or disparate.

## General Discussion

Taken together, the results of Experiments 1 and 2 suggested that both visual proximity and semantic proximity each played a key role in object identification. Members from sets of objects with multiple overlapping visual features *and* semantic features were harder to identify than members from sets of objects with minimal visual and semantic overlap. This deleterious effect of psychological proximity was apparent among both DAT patients and to a small (but significant) degree among healthy control observers. The key difference, however, was the devastating degree of impairment caused by these psychological proximity effects among the DAT patients (in the case of visually close shapes mapped to semantically close stringed instrument names, DAT performance was over 16 standard deviations poorer than control performance).

The utility of this episodic memory paradigm task in understanding object identification deficits ultimately depends on its relationship to veridical object identification. We propose that in their most important aspects, the two processes are analogous. In the E.L.M. task, on learning trials a blob is accompanied by an auditorially presented label. In order to succeed on test trials, participants must somehow learn to link these blobs to the labels that accompanied them on learning trials. One possibility is that participants may directly link the form of the blob to the blob’s “name” and store these pairings in episodic memory. A second possibility is the auditorily presented label on learning trials makes contact with the semantic attributes corresponding to that label. Despite the unusualness of the task, what gets stored in episodic memory is a traditional linkage that is habitually used in object recognition—a link where object form makes contact with semantics, which then contacts output phonology (the blob’s “name”). Choosing between these alternatives, the strong effect of semantic proximity for DAT patients suggests that the chosen pathway is the one that travels through semantics.

Thus, the blobs in the E.L.M. paradigm can be thought of as descriptions in shape space, just like the forms of real objects. Like real objects, these points in shape space make contact with relevant points in semantic space, which in turn make contact with output phonology. These mappings all likely take place in cascade fashion (Humphreys et al., 1988). The central difference between veridical object identification and identification in the E.L.M. paradigm, therefore, is that in veridical object identification these mappings between form, semantics, and phonology already exist, whereas in the E.L.M. paradigm these mappings must be instantiated in episodic memory.

Despite the fact that the E.L.M. paradigm involves episodic memory and confrontation naming or veridical object identification involves semantic memory, there appears to be a substantial correspondence between performance on these tasks. The best evidence for this correspondence comes from investigations with E.L.M. for whom we have data on both tasks. Unlike his nearly flawless performance with conjunction sets of blobs mapped to semantically disparate labels, E.L.M. committed 52% errors for bird labels, 33% errors using mammal labels, and 56% errors using stringed musical instrument labels (Dixon et al., 1997). Paralleling these results, E.L.M.’s confrontation naming of birds (90% errors *vs.* 10% errors for age matched controls) and animals (44% errors *vs.* 4% errors for controls) was quite poor, as was his performance with stringed musical instruments (80% errors) on a five-alternative picture–word matching task. In contrast, he made only 14% errors while naming line drawings of semantically unrelated artifacts.

One important difference between the E.L.M. paradigm and confrontation naming tests that rely on semantic memory is that in the E.L.M. paradigm one can limit the set size and impose restrictions on the foils from which the target stimuli must be disambiguated. Thus, although visually similar blobs mapped to “frog,” “donkey,” and “robin” constitute a set of visually similar but semantically disparate objects in the E.L.M. paradigm, the confrontation naming of an actual picture of a donkey involves disambiguating donkey from a host of entities stored in memory such as cow, horse, and pony; entities that are much more semantically proximate than “robin” and “frog.” Thus the item difficulty in confrontation naming depends on whether there are, within memory, competing entities that are visually and semantically close to the presented object, a factor that may involve the numerosity of a given category (Damasio, 1990). Despite such differences, we would argue that performance on both tasks is mitigated by the same general principle—that of psychological distance. As such, the most crucial, and beneficial difference between the E.L.M. task and confrontation naming tasks is that in the E.L.M. task one has empirical control over the contrasts between target and competitor objects required to make correct identifications.

An additional benefit of the E.L.M. paradigm is that it offers clues as to where in the object identification sequence disruptions may have occurred. In confrontation naming, it is possible that deficits are due to perceptual problems,

problems mapping form to semantics, or problems accessing the correct label for phonological output. In the E.L.M. paradigm, the fact that DAT patients show performance differences for identical shapes mapped to semantically close and distinct labels, suggests that the problem is not purely at the perceptual level. The fact that differences in performance are obtained for identical labels mapped to visually close and visually distinct shapes indicates that the problem is not purely with accessing the correct label for phonological output. Rather, the problem seems to involve the mappings between object form and the semantics appropriate to that object. Consonant with cascade models of object recognition (Humphreys et al., 1988), these problems are exacerbated when the forms of objects within a set are visually similar, and the semantics of the objects within a set are also similar.

In an object identification model in which points in shape space, make contact with points in phonological space *via* points in semantic space, it can be postulated that decreasing the distance between points in either semantic or shape space will serve to enhance the likelihood of object identification problems. The empirical data derived from this study clearly indicate that such decreases in the distance between points in shape space or in semantic space each contributed to object identification problems in DAT.

One way of accounting for the performance of DAT patients in these experiments is to assume that Alzheimer's disease is a kind of random pathological process which serves to selectively "pick off" knowledge about specific attributes of objects (Martin, 1992). As the disease progresses, more and more specific attributes become compromised. Thus, over time, the actual memory representations of all objects should become more and more similar to one another. For objects that are visually and semantically close to start with (e.g., lion, tiger, leopard) a random disease process that disrupts knowledge of a large percentage of attributes will cause tremendous object identification problems because there is a high likelihood that the few diagnostic attributes (e.g., stripes on a tiger, spots on a leopard) that serve to disambiguate semantically close exemplars have been destroyed. For objects that are visually and semantically distinct, however, losing knowledge of even a large number of these attributes should have less dire consequences, because there will still remain enough intact diagnostic attributes for exemplars to be adequately disambiguated.

By applying the notion of semantic degradation in the framework of current exemplar models, one can perhaps better understand the role of visual and semantic proximity in DAT object identification. In Estes' (1994) models, objects are stored in memory as multidimensional arrays. These arrays consist of dimensions devoted to coding attribute values on visual shape information (dimensions like curvature, thickness, and tapering) as well as dimensions encoding attribute values on semantic information. Psychological similarity is determined by making attribute by attribute comparisons. The more attributes in common, the greater the psychological similarity and the more attributes that differ,

the lesser the psychological similarity. Because visual attributes *and* semantic attributes each contribute to the overall psychological similarity, then, theoretically, two objects having exactly the same shape (e.g., the silhouette of a light bulb *vs.* the silhouette of a pear) could have very different psychological similarity values depending on the degree of overlap among their semantic attributes. Such appears to be the case in these experiments, where shapes mapped to the labels "carriage," "kite," and "wrench" are much better identified than exactly the same shapes mapped to the semantically close concepts violin, guitar, and banjo.

If Martin's theory is then applied to Estes' models, the resulting theory would predict that Alzheimer's disease could make psychologically similar objects even more psychologically similar if they happen to eliminate the knowledge of diagnostic attributes (by effectively zeroing these attribute values). Consider for example a DAT patient who has lost the knowledge that tigers have stripes. When making value by value comparisons between the semantics of tiger and lion, the surface markings of the two felines would be coded as being equivalent. Thus these patients would derive larger (i.e., closer) semantic similarity values for these two objects than DAT patients who realize that tigers and lions differ in terms of surface markings. Thus, in more advanced cases, patients' semantic representations may be so compromised that they know only that lions, tigers, and leopards are animals, but are unable to cite any of their specific attributes (Chertkow et al., 1989, 1992; Martin & Fedio, 1983).

If one assumes, therefore, that over the course of DAT, losing knowledge of key attributes makes psychologically close concepts even closer then one might expect to find the most serious object identification difficulties for exemplars with high numbers or overlapping visual and semantic attributes prior to any type of brain damage. Such appears to be the case for DAT patients: Mapping visually similar blobs to either the three carnivorous cat labels, or the three musical instrument labels in Experiment 2 results in significantly more confusions than when identical shape sets are mapped to concepts with few overlapping semantic attributes (unrelated artifacts or unrelated animals).

The combination of Experiments 1 and 2 suggest that both visual proximity and semantic proximity play a key role in object identification among a group of DAT patients. If the above contentions are correct, however, the obvious next step would be to assess the semantic integrity for each of these concepts and see how a given participants' semantic integrity influences their performance on this task.

This psychological distance view of category specific deficits contrasts with other models. Sartori and Job (1988), and Sartori et al. (1992), maintain that different categories of objects each have their own separate structural descriptions, and that category-specific identification deficits ensue following selective damage to only some of these structural descriptions. Consonant with this theory, Etcoff et al. (1991) suggest that certain classes of objects may require such specialized operations, arguing that, unlike arti-

facts, the structural descriptions for animals may require a set of zoomorphic visual primitives involving shapes defined by skin drawn over a three-dimensional skeleton filled out by muscle and fat. The current findings indicate, however, that object identification depends on more than just the structural factors intrinsic to structural descriptions. When object form is held constant, semantic proximity plays a crucial role in object identification systems damaged by Alzheimer's disease.

Silveri et al. (1991) have proposed that knowledge of biological and man-made categories are stored in different anatomical locations suggesting "a double dissociation between temporolimbic damage, selectively impairing semantic knowledge for living things, and left frontoparietal lesions, preferentially impairing semantic knowledge for non-living things" (Silveri et al., 1991, p. 545). This viewpoint would predict a sharp division between identifiable artifacts and unidentifiable biological objects. This viewpoint has trouble accounting for man-made objects like musical instruments, which often pose particular problems for patients who otherwise show deficits only for biological items (Damasio, 1990; Damasio et al., 1990a; Warrington & Shallice, 1984).

These exception categories have led Silveri and colleagues to frame category-specific deficits in terms of the types of information required to identify specific types of objects. Their investigation of the postencephalitic patient L.A., who, among other exceptions to the biological *versus* man-made distinction, showed impairments identifying musical instruments, has led them to speculate that what may be important is not whether a category is living or man-made, but rather the manner in which exemplars within categories are disambiguated. They speculate that

*contrary to what happens with most categories of man-made artifacts, the distinction between the various members of these two categories does not rely upon functional, but upon perceptual features (vision, taste, and smell in the case of food items, vision and sound in the case of musical instruments).* (Gainotti & Silveri, 1996, p. 383)

Warrington and colleagues (Warrington & McCarthy, 1987, 1994; Warrington & Shallice, 1984) were the first to propose that semantics may be parsed into knowledge concerning sensory properties (e.g., what the object looks like) and knowledge concerning function (what the object does). They suggested that if the knowledge of sensory properties becomes damaged, biological objects become unidentifiable because discrimination among exemplars relies primarily on visual features. Artifacts can still be identified because patients retain knowledge of their often unique functions. Thus, category specificity has nothing to do with biological category membership *per se*, but rather whether or not an object can be reliably defined according to its function.

Support for this view comes from a study by Lambon Ralph et al. (1997) who assessed confrontation naming of DAT patients at two time points. Patients' knowledge about the objects they were naming was also assessed at each point

by getting them to provide definitions. Objects were animals and artifacts (including musical instruments). Comparisons were made between object categories concerning the types of knowledge that was lost when objects could no longer be named at the second time point. For the definitions of artifacts that could no longer be named there was a dearth of functional information, whereas for animals that could no longer be named, there was a disproportionate lack of visual information within patients' definitions. Thus, in accordance with the position of Warrington and colleagues, functional information appears to underlie the ability to name artifacts, and visual information appears to provide the foundation for animal naming.

Further evidence in support of this parsing of semantics into visual and functional components comes from PET studies of healthy observers. Martin et al. (1996) used subtraction methodology to show that identifying animals draws upon ventral areas of the temporal lobes as well as primary visual cortex. Such preferential visual cortical activation for animals but not tools was interpreted as a reconsultation of the animal's fine-grained visual features in order to arrive at base-level identification. When people identify tools, temporal lobe activation is accompanied by activation in the premotor area of the left frontal lobe. Martin et al. attributed such frontal activity to activation of the cortical areas responsible for encoding knowledge about object function, since this same area is activated when participants are asked to imagine reaching for and grasping objects. Thus, as Warrington and colleagues suggest, the disambiguation of living things relies primarily on visual features, whereas, the disambiguation of objects like tools also involves their function.

In a sophisticated large-scale analysis of 116 patients with unilateral lesions, Tranel et al. (1997) found that person identification was disrupted primarily by damage to the right temporal pole, animal identification was disrupted by right hemisphere damage to the ventral temporal and mesiotemporal areas as well as the left mesial occipital regions, and tool identification was disrupted by left hemisphere damage to the occipital-temporal-parietal junctions. Tranel et al. (1997) are careful to point out that these regions are not "centers" in which the objects are stored. Rather, these regions are likely intermediary areas where information is gathered from a number of more primary sensory cortical areas where the multidimensional attributes of objects are actually processed. They suggest that the location of these intermediary zones are situated such that they can deal efficiently with the types of attribute information that must be processed in order to identify these objects. Thus, for tools that have both visual attributes as well as attributes concerning characteristic hand motions involved in their use, the intermediary zone is located in the occipital-temporal-parietal junction of the left hemisphere—an ideal location for receiving visual and functional information. For animals, which are associated primarily with visual attributes but not typically functional information (at least in terms of hand motions), the intermediary zone was in the right hemi-

sphere, and restricted to the medial and ventral portions of the temporal lobe (Tranel et al., 1997).

One category of interest concerning the functional *versus* visual account of category-specific deficits is musical instruments. A guitar has a salient function for man, along with specific hand movements associated with this function. If object function provides the underpinnings of artifact identification, why, then, should objects like a guitar pose problems for patients who otherwise have difficulties predominantly with biological objects? As Damasio (1990) and Gainotti and Silveri (1996) have suggested, it may be that these items, like animals, must be disambiguated based primarily on their visual features. Thus, it would appear that function is important for the disambiguation for some objects (e.g., tools) but not others (e.g., stringed musical instruments).

Invoking the notion of semantic distance may help to clarify why these exception categories are so problematic for patients who primarily have difficulties identifying living things. In exemplar model terms, if nonbiological objects like tools (e.g., saw and hammer) have *different* functions, this would serve to *increase* the semantic distance between the exemplars comprising these categories, thereby making these objects easier to identify. For objects like a guitar, however, their function and (at least concerning the left hand) the kinesthetic movements required to play these instruments, are very similar to the functions and kinesthetic movements associated with other exemplars within the subcategory of stringed musical instruments. Thus, it may be that in order to disambiguate violin, guitar, and banjo one may have to rely on subtle differences in both function, and subtle differences in the visual features comprising these instruments. This overlapping of structural, functional and kinesthetic attributes results in such objects being stored close together in multidimensional psychological space—a situation that elicits identification problems for these items.

The notion of semantic distance in the context of exemplar models of categorization and object identification may also account for the finding of Hodges et al. (1991), that relative to normals, DAT patients make an excessive number of superordinate naming errors. When shown simple line drawings, rather than responding with base level terms (e.g., beaver or camel), DAT patients will often give as a response the superordinate category to which the exemplars belong (e.g., animal). In accordance with this result Hodges et al. (1992) demonstrated that the ability of DAT patients to sort pictures into superordinate categories (e.g., land animals *vs.* birds) was relatively preserved compared to their abilities to sort pictures into categories based on whether they possess specific attributes (e.g., fierce *vs.* not fierce). In exemplar models (Estes, 1994; Kruschke, 1992) individual exemplar nodes converge on (and activate) specific category nodes. Although Alzheimer's disease may serve to disrupt knowledge of specific diagnostic attributes resulting in the inability to discriminate between exemplars such as lion and tiger, activation of intact (albeit overlapping) attributes (e.g., has fur, four legs) will cause the correct cat-

egory node (animal) to outactivate competing category nodes (e.g., tools, musical instrument). Thus, although unable to disambiguate exemplars at basic levels because of the loss of specific diagnostic attributes, DAT patients may be able to jump up to superordinate levels of abstraction (animals *vs.* tools) in order to carry out at least a rudimentary form of object identification.

The notion that the psychological distance between exemplars may determine whether or not DAT patients can disambiguate particular exemplars from competitors in memory may also explain certain findings pertaining to word frequency and familiarity. Both Hodges et al. (1991) and Chertkow et al. (1992) found that line drawings of objects with lower word frequency labels posed greater object identification difficulties for DAT patients. Similarly, Stewart et al. (1992) found that both word frequency and concept familiarity were positively related to object identification among herpes encephalitis patients. If exemplar similarity is determined by taking into account differences between exemplars attribute by attribute, then the more one knows about specific objects (i.e., the greater their familiarity), the greater the probability of encountering diagnostic attributes capable of differentiating objects. The more diagnostic attributes of which one is cognizant, the more resilient one will be to damage to this system, and hence the lower the likelihood of making within-category object confusions.

## Conclusions

Irrespective of cognitive neuropsychologists' views of exemplar models and the notion of psychological distance, the paradigm employed in these experiments offers an unprecedented ability to look directly at the influence of semantics in object identification. In almost all previous studies investigators have used line drawings of objects in order to try and uncover the nature of category-specific identification deficits. In such studies, both the shape primitives of the objects were unknown and the forms of the objects were inextricably yoked to the semantics of the objects themselves. This combination makes it difficult if not impossible to isolate the influence of semantics in object identification from the influence of how the forms are processed at the structural level.

The present paradigm, however, represents a first in neuropsychology in that the ramification of semantics on object identification can be decoupled from the structural form of the object. By allowing the same shapes to stand for concepts that differed in semantic proximity we have effectively held the structure of the objects constant, while independently manipulating their semantic properties. In so doing, this paradigm provides a kind of microscope for looking at the semantic proximities among objects. The formidable resolving power of this semantic microscope is evident when looking at DAT performance for the "lion"–"tiger"–"leopard" *versus* the "lion"–"tiger"–"zebra" label sets of Experiment 2. Using this paradigm significant performance decrements were detected despite the relatively subtle change

in semantic proximities effected by replacing “zebra” with “leopard.” Viewed using a lower resolution, this paradigm clearly shows that the degree of difficulty DAT patients have identifying objects is a combination of both visual and semantic proximity.

It can be postulated that, in real life, many man-made objects are visually dissimilar and hence pose fewer object identification problems than objects that share visual features. Further, many man-made objects often have specific functions—a situation that might serve to increase the semantic distance between exemplars within categories, thereby rendering them even less confusable. Exceptions are categories like musical instruments that are both visually similar and have a plethora of overlapping semantic attributes.

Like musical instruments many categories of biological objects are similar in both structure and in meaning (all birds have heads, beaks, wings, and tails and all birds sit in trees, lay eggs, sing, etc.) Thus objects like birds, fruits, vegetables, animals, and insects pose the requisite combination of semantic proximity of concepts *and* shared visual features that serve to exacerbate object identification deficits in patients suffering from dementia of the Alzheimer type.

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