

Domain-Specific Knowledge Systems in the Brain: The Animate-Inanimate Distinction

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Abstract

We claim that the animate and inanimate conceptual categories represent evolutionarily adapted domain-specific knowledge systems that are subserved by distinct neural mechanisms, thereby allowing for their selective impairment in conditions of brain damage. On this view, (some of) the category-specific deficits that have recently been reported in the cognitive neuropsychological literature—for example, the selective damage or sparing of knowledge about animals—are truly categorical effects. Here, we articulate and defend this thesis against the dominant, reductionist theory of category-specific deficits, which holds that the categorical nature of the deficits is the result of selective damage to noncategorically organized visual

or functional semantic subsystems. On the latter view, the sensory/functional dimension provides the fundamental organizing principle of the semantic system. Since, according to the latter theory, sensory and functional properties are differentially important in determining the meaning of the members of different semantic categories, selective damage to the visual or the functional semantic subsystem will result in a category-like deficit. A review of the literature and the results of a new case of category-specific deficit will show that the domain-specific knowledge framework provides a better account of category-specific deficits than the sensory/functional dichotomy theory.

INTRODUCTION

How is conceptual knowledge organized in the brain? Evidence relevant to this issue is provided by the patterns of semantic processing deficits in brain-damaged subjects, especially those deficits that seem to selectively affect one or another semantic category. The first clear demonstration of a semantic category-specific deficit was made by Warrington and Shallice (1984). They reported four patients recovering from herpes simplex encephalitis who were disproportionately impaired in producing and understanding the names of living things. This result, coupled with the observation of a brain-damaged subject who showed the reverse dissociation—that is, relative sparing of the comprehension of living relative to nonliving things¹ (Warrington & McCarthy, 1983)—invited the inference that brain damage could result in category-specific semantic deficits.²

Although the four cases described by Warrington and Shallice (1984) were not all tested with the same tasks or the same materials, they all showed poorer performance in producing and/or comprehending the names of living as opposed to nonliving things. In some cases the contrast in performance was quite striking: J.B.R. was only able to recognize or name 2 of 48 living things (animals or plants) but accurately described or named 45 of 48 nonliving things; similarly, S.B.Y. failed to identify any of the living items but correctly identified 36 of 48 nonliving things. For example, J.B.R. defined *briefcase*

as “small case used by students to carry papers” but responded “don’t know” to the word *parrot*; similarly, S.B.Y. defined *towel* as “material used to dry people” but responded “bird that flies” to the word *wasp*. The other two cases reported by Warrington and Shallice, K.B. and I.N.G., could not be tested with the definition production tasks because of their severe language production deficits, but their performance in word/picture matching tasks was poorer for animals than for nonliving things. Thus, all four cases showed disproportionate difficulty for living than for nonliving things.

Confirmation of the dissociation of performance for living and nonliving things was soon obtained in many other studies of brain-damaged subjects of various etiologies, including other cases of herpes simplex encephalitis, trauma, cerebro-vascular accident, and neurosurgery (Basso, Capitani, & Laiacona, 1988; Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; De Renzi & Lucchelli, 1994; Farah, Hammond, Mehta, & Radcliff, 1989; Farah, McMullen, & Meyer, 1991; Hart & Gordon, 1992; Hillis & Caramazza, 1991; Laiacona, Barbarotto, & Capitani, 1993; Laiacona, Capitani, & Barbarotto, 1997; McCarthy & Warrington, 1988; Pietrini, Nertempi, Vaglia, Revello, Pinna, & Ferro-Milone, 1988; Powell & Davidoff, 1995; Sartori & Job, 1988; Sheridan & Humphreys, 1993; Silveri & Gainotti, 1988; Sirigu, Duhamel, & Poncet, 1991). And there have also been several reports documenting the reverse pattern of dissociations—that is, cases of impaired performance in naming and/or recognizing nonliving ob-

jects in the face of spared ability with living things (Hillis & Caramazza, 1991; Sacchett & Humphreys, 1992; Warrington & McCarthy, 1983, 1987). It would seem, then, that the category of living things can be damaged independently of the category of nonliving things, thus inviting the inference that the semantic system might be organized categorically. Furthermore because most of the patients with selective impairment of the living category had sustained damage to (at least) the left temporal lobe, it might be further surmised that the latter neural structure is part of a neural network specifically dedicated to representing conceptual knowledge about living objects.³

Despite the seemingly categorical nature of the deficit, the inference that the semantic system is organized categorically has never been entertained seriously (but see Warrington, 1981). The obstacle most often cited against a categorical interpretation of the category-specific semantic deficits was apparent from the earliest results: The patterns of semantic categories affected in any one patient did not correspond to plausible, clear-cut categorical distinctions such as the living/nonliving or natural kind/artifact dichotomies. For example, the early, paradigm cases J.B.R. and S.B.Y. were both impaired not only in processing the animal and plant categories but also foods. Clearly, there is no obvious way in which the food category could be easily subsumed within the living thing category (think of spaghetti, rice pudding, etc.). Furthermore, extensive testing of J.B.R. showed that he was also impaired in defining musical instruments, precious stones, cloths, and metals—all inanimate objects—but not body parts (which according to some authors should be associated with living things). These violations of the simple dichotomy of living/nonliving things led Warrington & Shallice (1984, see also Warrington & McCarthy, 1983, 1987) to propose the sensory/functional theory of category-specific deficits. They argued that functional and visual (sensory) attributes are not only differentially important for the identification of nonliving and living things, respectively, but also for other categories such as food. Damage to the visual semantic subsystem results in disproportionate impairment of the categories of living things and foods because the identification of the members of these categories depends crucially on their visual (sensory) features, and damage to the functional semantic subsystem results in disproportionate impairment of nonliving things because identification of the members of this category of objects depends crucially on their functional, nonsensory attributes. In other words, the seemingly categorical nature of semantic deficits does not reflect the categorical organization of conceptual knowledge in the brain but is merely the accidental consequence of a more basic, noncategorical organizing principle of the semantic system.⁴

The rejection of the possibility that conceptual knowledge might be organized categorically in the brain may

have been premature. Here we show that the evidence usually cited in favor of reductionist accounts of category-specific deficits is far from compelling. However, before doing so we consider whether the reported category effects are real or just artifacts of uncontrolled stimulus variables.

Are Category-Specific Deficits Artifacts of Uncontrolled Stimulus Factors?

Warrington and Shallice (1984) raised and dismissed the possibility that the category-specific deficits they reported might have arisen from frequency or familiarity differences between the members of the living and nonliving categories. In an identification experiment with word and picture stimuli, their subject S.B.Y. performed far worse with the living than the nonliving category even when familiarity and frequency were taken into consideration through covariance analyses. This precaution has not always been observed in other studies (or even the other cases in Warrington and Shallice's paper). It is not inappropriate, therefore, for Funnell and Sheridan (1992), Gaffan and Heywood (1993), and Stewart, Parkin, and Hunkin (1992) to raise the question of whether putative cases of category-specific deficits for living things might not simply reflect the fact that these items tend to be of lower frequency and familiarity and more visually complex than nonliving things. This concern is not unfounded because frequency, familiarity, and visual complexity have powerful effects on performance.

Stewart et al. (1992) provide the clearest demonstration of the need for caution in interpreting putative cases of category-specific deficit of living things. They report a case, H.O., with herpes simplex encephalitis, whose performance in naming the Snodgrass and Vanderwart (1980) pictures showed a significant category effect, with poorer performance for the living than nonliving category (65% versus 86%). The difference between categories remained even when the lists were matched for word frequency (42% versus 80% for living and nonliving, respectively). However, when the two categories were matched jointly for frequency, familiarity, and visual complexity, the category effect disappeared (42% versus 36% for living and nonliving things, respectively). Furthermore, when the categories were redefined in terms of the extent to which sensory (animals, vegetables, fruit, large buildings, and natural features) versus functional (tools and kitchen utensils) attributes are supposedly more important in determining the meaning of category members, there again was no difference between categories when frequency, familiarity, and visual complexity were jointly controlled (57% versus 58%, respectively). These results, together with those of Funnell and Sheridan (1992), who showed that item familiarity can be a major determinant of naming accuracy, and the results of Gaffan and Heywood (1993), who showed

that living and nonliving things differ in visual discriminability and consequent ease of recognition, indicate that putative cases of selective deficit of the living category may not, in fact, be true category-specific deficits but may instead reflect category nonspecific processing difficulties that are more severe for low-frequency, low-familiarity, and hard-to-discriminate visual objects.

The results reported by Funnell and Sheridan (1992), Gaffan and Heywood (1993), and Stewart et al. (1992) demand that we adopt a cautious stance in interpreting supposed cases of category-specific deficits. Nonetheless, there is compelling evidence that not all putative cases of category-specific deficits can be explained by appeal to between-category variation in item frequency, familiarity, and visual complexity. First, just as was the case for S.B.Y. (Warrington & Shallice, 1984), other cases of disproportionate difficulty in naming and recognizing living things continue to show the effect even when frequency, familiarity, and visual complexity are taken in consideration (e.g., Farah, Meyer, & McMullen, 1996; Gainotti & Silveri, 1996; Hart & Gordon, 1992; Kurbat, 1997; Laiacona, Barbarotto, & Capitani, 1993; Laiacona et al., 1997; Sartori, Miozzo, & Job, 1993; Sheridan & Humphreys, 1993). Thus, for example, Sartori et al. retested their subject Michelangelo (Sartori & Job, 1988) with animals and artifacts matched for frequency, familiarity, and visual complexity and once again found that he named animals significantly less accurately than artifacts (30% versus 70%). Second, there are a number of reports of disproportionate deficit for the category of nonliving things (Hillis & Caramazza, 1991; Sacchett & Humphreys, 1992; Warrington & McCarthy, 1983, 1987)—the supposedly easier-to-process category.

Especially informative in this context is Hillis and Caramazza's (1991) report of two cases with contrasting category-specific deficits who were tested with the same stimuli on the same tasks. One subject, P.S., who had sustained bilateral temporal lobe and left frontal damage from a severe blow to the head, showed a disproportionate deficit with living things; the other case, J.J., who had sustained left temporal lobe and basal ganglia damage following a thromboembolic stroke, showed a disproportionate deficit for inanimate objects. The results reported for these two cases are striking: over seven administrations of a naming test, at 4 months postinjury, J.J. named animals ($n = 46$ in each test) and inanimate objects (including fruits and vegetables; $n = 98$ in each test) with an average accuracy of 81% and 12%, respectively; P.S. named living things (animals, fruits, and vegetables) and nonliving things with an average accuracy of 47% and 93%, respectively. The two subjects were tested again 13 months postinjury, when their performance had improved substantially. Their respective category-specific deficits were still clearly apparent: J.J. named correctly *all* animals but only 68% of inanimate objects; P.S. named correctly *all* nonliving objects but only 64% of living

things. These patients' category-specific deficits were not restricted to naming tasks but extended to comprehension tasks: J.J. demonstrated comprehension of all animal names but defined incorrectly or gave ambiguous responses to 23 of 98 nonanimal names; P.S. understood correctly all names of artifacts but defined incorrectly or gave ambiguous definitions to 11 of 70 animal names. Clearly, it is not possible to explain these contrasting patterns of category-specific deficits by appealing simply to between-category variation in item frequency, familiarity, and/or visual complexity. Indeed, the selective *sparing* of the animals category in J.J. unambiguously indicates that conceptual knowledge can be damaged along the boundaries of semantic categories.

The conclusion to be drawn from the fact that selective impairment of the living category is not always reducible to an effect of frequency, familiarity, and/or visual similarity (e.g., Sartori et al., 1993) and the fact that knowledge of the living category can be selectively spared (e.g., Hillis & Caramazza, 1991) is not, however, that all putative cases of category-specific deficits are to be taken as such. Funnell and Sheridan's (1992) and Stewart et al.'s (1992) admonition against the facile interpretation of performance differences between categories of items as having a categorical basis remains generally valid—it is valid for the brain-damaged subjects they studied, and it is likely to be valid for some of the other putative cases of category-specific deficit.

There are at least three implications that follow from the foregoing discussion. These concern the frequency of occurrence of different types of category-specific deficits, the types of categories affected, and the putatively disproportionate impairment in processing visual versus functional attributes by subjects with category-specific deficit for living things. The first two points are obvious, if not less important because of that. Although there is a clear asymmetry in the number of reported cases of living versus nonliving category-specific deficits (e.g., Gainotti & Silveri, 1996; Saffran & Schwartz, 1994), we cannot be sure of the magnitude of the putative asymmetry because most of the reported studies did not match category items on the variables of familiarity and visual complexity. Similarly, although there are many reports of deficit or sparing of one or another highly specific category (e.g., musical instruments, gemstones, geographical places, outdoor objects, etc.) their validity must remain in question because the items in these categories were also not specifically controlled for nuisance variables that might have led to their spuriously low or high levels of performance. And, as we shall argue more extensively below, the cautionary moral to be drawn from Stewart et al.'s (1992) paper, in particular, extends beyond the issue of whether a differential pattern of performance across categories is to be ascribed a categorical status. The implications also extend to claims about various cases of putatively disproportionate impairment in processing visual versus functional infor-

mation for the category of living things, because in these cases, too, there may have been inadequate control of the relative difficulty of visual and functional test items.

Having argued that at least some category-specific deficits are real category effects (i.e., not artifacts of uncontrolled stimulus factors), we now consider in detail two reductionist accounts of category-specific deficits.

The Sensory/Functional Theory

The received reductionist account of category-specific deficits is based on the role of sensory and functional properties in determining the meaning of living and nonliving things (Allport, 1985; Gainotti & Silveri, 1996; Hart & Gordon, 1992; Shallice, 1988; Silveri & Gainotti, 1988; Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984). There are several variants of this theory, but they all share two assumptions: (1) conceptual knowledge is organized in the brain by modality (visual, olfactory, motor/functional, etc.) and (2) sensory and functional properties are differentially important in identifying members of the living and nonliving categories, respectively. We refer to this class of accounts as the *sensory/functional theory* (SFT).

The most widely discussed variant of this modality-based theory of semantics is the multiple semantics theory proposed by Warrington, Shallice, and McCarthy (Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984), which draws a fundamental distinction between so-called visual and verbal semantics. The other crucial assumption of the SFT is that the visual properties of concepts are much more important for distinguishing among members of living than nonliving things. A consequence of these assumptions is that selective damage to the visual semantic subsystem should result in disproportionate impairment for the living category—and, hence, a category-specific deficit. A further expectation derived from this model is that damage to the visual semantic subsystem should result in disproportionate difficulty with visual properties of the living things category.⁵ A computationally based variant of the SFT (Farah & McClelland, 1991) has confirmed the basic predictions derived from the original proposal by Warrington, Shallice, and McCarthy.

Two types of evidence have been cited in support of the SFT and against a categorical account of category-specific deficits: (1) category-specific deficits supposedly do not fall out neatly along the boundaries on which the living/nonliving categories divide, and (2) category-specific deficits are supposedly also modality-specific—that is, subjects with selective deficits for items in the living things category are supposedly more impaired in processing their visual than their functional properties (although they may also be impaired in processing the latter). We discuss these two types of evidence in turn.

What Are the Categories of Category-Specific Deficits?

The four cases of category-specific deficit described in Warrington and Shallice's (1984) seminal report were all impaired in processing not only living things but also foods. Furthermore, one of the four patients who was tested with a more extensive set of categories (J.B.R.) was also impaired with the categories of musical instruments, precious stones, diseases, cloths, and metals. Warrington and Shallice speculated that the co-occurrence of deficits to specific categories observed in these patients was not accidental but reflects instead the fact that the meanings of the items in the impaired categories depend more heavily on the *same* damaged semantic subsystem. That is, the co-occurrence of deficits for the categories of animals, foods, plants, and musical instruments was assumed to reflect the fact that the meanings of the members of these categories are distinguished primarily by their visual properties, whereas the members of the spared categories (e.g., furniture, vehicles, tools, etc.) are distinguished primarily by their functional attributes.

Although one of the more robust associations of category-specific deficits is that between the categories of animals and foods (De Renzi & Lucchelli, 1994; Sheridan & Humphreys, 1993; Silveri & Gainotti, 1988; Warrington & Shallice, 1984), there are a number of violations to this empirical generalization: There are patients with category-specific deficits who are impaired for animals (and fruits and vegetables, in some cases) but not food (Hart & Gordon, 1992; case J.J.: Hillis & Caramazza, 1991; Laiacina, Barbarotto, & Capitani, 1993) or who are impaired in naming food items but not animals (case P.S.: Hillis & Caramazza, 1991).⁶ Similarly, the association of deficits of living things and musical instruments, which was observed in some of the early reports of category-specific deficit (Silveri & Gainotti, 1988; Warrington & Shallice, 1984), has not held up. Thus, for example, the patient reported by De Renzi & Lucchelli (1994), who was otherwise very similar to those reported by Silveri and Gainotti and by Warrington and Shallice, performed very well with musical instruments. And although there have been a number of reports of selective damage or sparing of the category of living things (animals, fruits, and vegetables; e.g., case P.S.: Hillis & Caramazza, 1991; Laiacina, Barbarotto, & Capitani, 1993), it too dissociates, but along theoretically interesting lines: The category of animals can be damaged or spared independently of the category of fruits, vegetables, and plants (Hillis & Caramazza, 1991; Hart & Gordon, 1992), and the category of fruits and vegetables (or plants) can be damaged selectively (Farah & Wallace, 1992; Hart, Berndt, & Caramazza, 1985) from other living and nonliving categories.

It is far from obvious that the SFT can make sense of the attested patterns of associations and dissociations of category-specific deficits. The first problem concerns

whether it is reasonable to assume that the observed *associations* of category-specific deficits reflect the organizing principle of modality-specific semantics. Thus, what underlying sensory/functional principles would group together the categories of animals, foods, and musical instruments versus the categories of furniture, tools, and body parts? The mere assertion that the meanings of the items in the first set are more dependent on visual or other sensory attributes and those of the second set are more dependent on functional attributes is not particularly convincing. Consider, for example, the contrast among carrot, celery, apple, orange, avocado, tomato, hamburger, scrambled eggs, pasta, beer, and wine. These items are clearly visually different from one another, but they are also functionally different. One might go so far as to contend that what is important for discriminating among them is not so much their visual shape but their functions: used to make juice, used for dessert, eaten at breakfast, Italian food, fast food, eaten raw, eaten cooked, used for minestrone, and so on. The same argument can be made for musical instruments with respect to the importance of their functional properties. And certainly visual shape is as important for distinguishing hands, heads, beds, stools, hammers, and screwdrivers as is their function. Nonetheless, the claim that the relative “weighting” of the sensory and functional properties for discriminating among members of a semantic category provides the binding factor for some of the observed associations of category-specific deficits has never been developed in enough detail to allow serious consideration of its merits.⁷

Far more damaging to the SFT is the pattern of *dissociations* of category-specific deficits. Since part of the motivation for the SFT is the claim that certain semantic categories tend to be damaged together because of their common dependence on a modality-specific semantic subsystem, the observation that these same categories can be damaged independently of each other poses a serious threat to the theory. That is, in the measure to which one is committed to explaining the observed co-occurrence of impairment of, for example, the categories of animals and of fruits and vegetables as reflecting their shared dependence on the hypothesized visual semantic subsystem, one is thereby committed to their necessary co-occurrence, and their dissociation would constitute evidence against the hypothesized semantic subsystem.

Warrington and McCarthy (1987) were keenly aware of this danger to the SFT and tried to deal with it by hypothesizing further subdivisions within the visual semantic subsystem. They argued that the dissociation of deficits of the categories of animals and of fruits and vegetables may be explained by assuming that some perceptual features are more important for animals than for fruits and vegetables, and vice versa for some other perceptual features. They speculated that shape may be

more important for the categories of flowers and animals and that color may be more important for the category of fruits and vegetables. And, presumably, in order to explain the other patterns of dissociations of category-specific deficits (e.g., animals from flowers; animals from musical instruments) further subdivisions would have to be specified within the visual and functional semantic subsystems. However, no independent evidence has been provided for the claim that distinction among members of different semantic categories depend differentially on color, shape, or other sensory features. Nor has it been shown that impairment of particular semantic categories is associated with special difficulties for specific types of sensory information (e.g., greater difficulty processing color in patients with selective damage to the categories of fruits and vegetables). Furthermore, it should be noted that the more subdivisions one proposes, specifically in order to accommodate dissociations of particular categories, the more this proposal becomes indistinguishable from a categorical account of category-specific deficits.

The evidence and arguments presented in this section have shown that one of the pillars of the SFT does not hold. Contrary to the early reports of category-specific deficits that stressed the co-occurrence of conceptually disparate combinations of categories (e.g., animals, foods, and musical instruments), there are a number of well-documented cases of dissociations of these categories. And, as we have seen, there appears to be no clearly motivated basis for the argument that attested patterns of associations and dissociations of semantic category deficits are readily explicable in terms of selective damage to modality-specific semantic subsystems. These criticisms of the SFT undermine its supposed superiority over categorical accounts in explaining the occurrence of category-specific deficits. We turn now to the other major argument for the SFT—the claim that patients with selective damage to the living category are disproportionately impaired in processing their visual properties.

Is Knowledge of Visual Properties More Severely Impaired Than Knowledge of Functional Properties in Individuals with Category-Specific Deficits for Living Things?

The claim that semantic category-specific deficits reflect selective damage to the visual or to the functional⁸ semantic subsystems predicts that subjects with selective damage to the living or the nonliving categories should show disproportionate difficulty with visual or functional properties, respectively. This expectation is derived not only from Warrington, Shallice, and McCarthy's theory (Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984) of the semantic system but also from the computational variant proposed by Farah

and McClelland (1991). The results of several studies have been interpreted as having confirmed this prediction. That is, there are reports of subjects with disproportionate impairment of the category of living things who are also supposedly disproportionately impaired in processing the visual attributes of living things.

The first studies that explicitly addressed the possibility of a co-occurrence of category- and modality-specific semantic deficits are those of Basso et al. (1988), Sartori and Job (1988),⁹ and Silveri and Gainotti (1988). In all three studies, it was reported that subjects with disproportionate difficulty with living things also had disproportionate difficulty responding to questions about the visual attributes of living objects. For example, Basso et al. report that their subject (N.V.) correctly answered 25 of 29 questions about the functional attributes of living things (e.g., Does it live in Italy or in the desert?) but only 10 of 20 questions about their sensory attributes (e.g., Does it have a smooth back or is it humpbacked?). Similarly, subject L.A. (Silveri & Gainotti, 1988) was only able to name 1 of 11 animals in response to definitions that stressed visual attributes (e.g., a black and white striped wild horse) but could name 8 of 14 animals in response to definitions that stressed functional attributes (e.g., the king of the jungle).

Later studies also purportedly showed an association of category- and modality-specific semantic deficits (De Renzi & Lucchelli, 1994; Farah et al., 1989; Gainotti & Silveri, 1996; Hart & Gordon, 1992). Thus, for example, Farah et al. report that their subject L.H. was disproportionately impaired in answering questions about visual attributes of living things (e.g., Do ducks have long ears? vs. Is peacock served in French restaurants?). And De Renzi and Lucchelli report that their subject Felicia was significantly worse at answering questions about physical than “functional-encyclopedic” attributes of living things but that she showed no such difference for nonliving things.

Despite the seeming convergence of results in favor of the possibility that category-specific deficits are also modality-specific, there are reasons for skepticism in interpreting these results. First, there are issues concerning the validity of the reported results in each of the studies cited; second, there is growing evidence that category-specific deficits are *not* associated with disproportionate difficulties in processing either the visual or the functional attributes of objects.

Interpretation of some of the studies purporting to show that patients with category-specific deficits for living things are also disproportionately impaired in processing these objects’ visual attributes is undermined by the fact that these studies failed to control the relative difficulty of visual and functional attribute judgments. Stewart et al. (1992; Exp. 5) have shown that judgments about the visual properties of living things are more difficult to evaluate than judgments about functional properties. They have also shown that the disproportion-

ate difficulty for visual attributes for living things in a patient with a putative category-specific deficit disappears when visual and functional judgments are matched for difficulty (Exp. 6). In light of these results, it is not possible to meaningfully interpret some of the early studies claiming to show a co-occurrence of category- and modality-specific deficits, where no attempt was made to control the relative difficulty of visual and functional attribute judgments (e.g., Basso et al., 1988; Sartori & Job, 1988; Silveri & Gainotti, 1988¹⁰).

A related difficulty is encountered by De Renzi and Lucchelli’s (1994) study. Although the authors were able to show that their subject, Felicia, was more severely impaired in processing visual attributes of living than nonliving category items, she was also impaired in processing functional attributes of living things, as indicated, for example, by her performance in deciding whether an animal was native of Italy (only 73% correct). Furthermore, since no attempt was made to equate visual and functional judgments for difficulty, it is not possible to directly compare relative performance for the two types of judgments.

Farah et al. (1989) argued that their subject, L.H., presented with a category-specific deficit for the living category that was also modality-specific for visual properties. However, inspection of their data (Table 1, Farah et al.) shows that normal subjects were also disproportionately poor in answering questions about the visual properties of the living category. Thus, no meaningful conclusion concerning category-specific deficits is possible from this study.

Recently, Gainotti and Silveri (1996) retested their subject, L.A., with new materials designed to be free of the methodological problems encountered by their earlier report. They again showed that L.A. performed disproportionately poorly on tasks involving the processing of visual attributes of living things. For example, in a task requiring the identification of the visual feature on which two objects differed, they found that L.A. performed worse with animals (15% correct) than artifacts (50% correct). However, the two categories were also *significantly* different in familiarity (on a scale of 1 to 5, 2.55 and 3.96 for animals and artifacts, respectively). And in a color feature naming task in which L.A. again performed more poorly with living than nonliving things, there, too, the two categories differed in familiarity. Thus, the interpretation of L.A.’s performance regarding the putative association of category- and modality-specific deficits remains problematic at best.

Finally, Hart and Gordon (1992) have also argued for a modality-specific organization of the semantic system on the basis of the performance of their subject, K.R., who presented with a category-specific deficit restricted to animals. K.R. performed very poorly in naming animals (18 of 61) despite being perfectly normal in naming other objects (348 of 350). The striking feature of this subject was that she could answer correctly *all* ques-

tions about functional attributes of animals, as well as *all* questions about both visual and functional attributes of inanimate objects but was quite poor in answering questions about the visual attributes of animals. Thus, this case would seem to represent the perfect dissociation in support of the SFT.¹¹ However, there are aspects of this subject's performance that are problematic for the SFT, and there are other features of her performance that may undermine its usefulness altogether.

The fact that K.R. was impaired in processing the visual properties of only animals is inconsistent with the SFT. The theory predicts that damage to visual semantics would differentially affect the living and nonliving categories. It does *not* predict that it would lead to damage to only the category of animals. At the very least it predicts impairment of other living things (e.g., fruits) besides animals, as well as less-marked impairment of the nonliving category. None of these conditions were met by the results of this study. Equally problematic for the SFT is the fact that K.R.'s deficit in processing visual properties of animals was restricted to language inputs. She only performed poorly with visual attributes when she was required to respond to verbal inputs or to respond verbally. Thus, for example, she performed perfectly in distinguishing between appropriately and inappropriately colored animals but could not perform the same discrimination when the color alternatives were given verbally. This result is also highly problematic for the SFT. The theory predicts equal difficulties (barring additional sensory or language deficits) for visual and verbal tasks because damage to the visual semantic subsystem would presumably lead to impairments in all tasks involving the use of this system. Thus, K.R.'s selective difficulty for *visual properties* restricted to the *verbal domain* is uninterpretable within the SFT.

Perhaps, most problematic about the Hart and Gordon (1992) study is their subject's performance in a forced-choice property judgment task. In this task K.R. was required to choose between two visual or two nonphysical properties of animals (e.g., Is an elephant orange or gray? or Is an elephant a food or an animal?). The properties were chosen in such a way that they included properties that she had produced correctly and incorrectly in a previous direct recall task (e.g., What's the color of lemon? Yellow; What's the color of an elephant? Orange). In this task she virtually always (186 of 187) picked the choice corresponding to the property she had produced in the previously administered property naming task, whether correct or incorrect. Thus, for example, consistent with her response in the property production task, she chose orange when given the choice, Is an elephant orange or gray? She chose the incorrect, strange response in 54 out of 55 trials. The unexpected systematicity of K.R.'s strange errors raises questions about the usefulness of this study for informing theories of normal language because it appears that she may have come to have systematic "strange beliefs"

about some animals.¹² Nevertheless, the most that can be concluded for the SFT from the Hart and Gordon study is that those aspects of K.R.'s performance that are not strange are not explicable within the theory.

This review of the experimental evidence cited in support of the claim that subjects with a category-specific deficit for living things are disproportionately impaired in processing the visual features of concepts has shown it to be inadequate for the stated purpose. In each case (with the exception of Hart and Gordon, 1992, but there are other problems with this study), the failure to adequately control for differential levels of difficulty in processing visual versus functional properties of concepts undermines the possibility of drawing clear inferences from the results.¹³ Thus, there is no compelling empirical evidence in favor of the claim that category-specific deficits are also necessarily modality-specific deficits. Furthermore, there is growing evidence that subjects with category-specific deficits for living things are equally impaired in processing visual and functional attributes of objects—evidence that is directly in conflict with the SFT.

Laiacina, Barbarotto, & Capitani (1993) and Laiacina et al. (1997) have provided the clearest evidence to date for equal levels of impairment for visual and functional attributes in cases of category-specific deficit for living things. In the earlier of the two studies, they reported two trauma cases, F.M. and G.R., with disproportionate impairment in processing living things (F.M.: 20% vs. 70% correct naming of living and nonliving things, respectively; G.R.: 13% vs. 73% correct naming of living and nonliving things, respectively). When these subjects were tested in a forced-choice task with strictly matched questions about visual or functional properties of objects (Laiacina, Barbarotto, Trivelli, & Capitani, 1993), they performed equally poorly with the two types of attributes. Thus, F.M. responded correctly 73% and 69% of the time to questions about visual and functional properties of living things, respectively, and he responded correctly 96% of the time to both visual and functional properties of nonliving things. Similarly, G.R. responded correctly 55% and 58% of the time to questions about visual and functional properties of living things, respectively, and he responded correctly 91% of the time to visual properties and 84% of the time to functional properties of nonliving things. In a more recent study, Laiacina et al. (1997) again observed equal levels of impairment for knowledge of visual and functional attributes in two new cases of category-specific deficit for living things.¹⁴

Two other studies (Funnell & De Mornay Davies, 1997; Sheridan & Humphreys, 1993) further confirm this pattern of results. Sheridan and Humphreys reported a subject with a category-specific deficit for living things who was equally impaired with visual and functional attribute judgments (14 of 20 and 13 of 20 for visual and functional attributes of animals, respectively). And in a new

analysis of J.B.R., one of the cases of category-specific deficit for living things originally reported by Warrington and Shallice (1984), Funnell and De Mornay Davies (1997) found that he is equally impaired in verifying visual and functional attribute questions about living things.¹⁵ These results indicate that knowledge of visual attributes of living things is not necessarily disproportionately impaired (relative to knowledge of functional attributes) in subjects with a category-specific deficit for living things. Thus, the second of the two major predictions of the SFT is not confirmed.

The Organized Unitary Content Hypothesis (OUCH)

Another class of reductionist hypotheses rejects the modality-specific¹⁶ claim of semantic organization proposed by the SFT but also explains category-specific deficits as resulting from noncategorical properties of semantic representations. The OUCH is one such account (Caramazza, Hillis, Rapp, & Romani, 1990; Hillis, Rapp, & Caramazza, 1995; Rapp, Hillis, & Caramazza, 1993; see Riddoch, Humphreys, Coltheart, & Funnell, 1988, for a related proposal). This account is based on two fundamental characteristics of natural kind objects and artifacts: (1) the properties that define an object (e.g., dog, chair, etc.) are highly intercorrelated, and (2) members of a superordinate category share many features in common (S. Gelman & Coley, 1990; Keil, 1989; Markman, 1989; Rosch, 1973, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Thus, for example, objects that are capable of a certain type of bio-mechanical motion (like a dog) tend to have particular types of shapes and to be made of certain kinds of “stuff” (texture, color, odors, etc.), and objects that have a particular shape (like a chair) and an inability to move tend to be made of different kinds of “stuff.” Furthermore, these bundles of intercorrelated properties are differentially distributed in the categories of living and nonliving things. A consequence of the latter property of concepts is that the multidimensional space of semantic properties is not homogeneously occupied but, instead, is “lumpy”—there are regions that are densely packed and others that are only sparsely occupied.¹⁷ The denser regions represent concept domains characterized by highly correlated properties, with the densest regions most likely corresponding to natural kind concepts; however, some artifacts (e.g., tools) can also occupy relatively dense regions, because they, too, may share many correlated properties (e.g., shape and function).

One implication of the inhomogeneous nature of the organization of semantic attributes in the brain is that focal damage to the semantic system can result in category-specific deficits. This expectation is based on the following reasoning: Focal damage to a region of semantic space will result in an impairment of those categories whose members’ meaning depends on the affected se-

mantic properties, and because of the lumpiness of semantic space, the impairment is likely to be disproportionate for one category or another, reflecting which dense region happened to have been damaged. Two other implications follow from the OUCH model. One is that semantic categories with highly correlated properties (i.e., natural kinds) are more likely to be damaged as a category. This expectation follows from the assumption that categories with highly correlated properties occupy dense regions in semantic space, thereby allowing for the possibility of selective damage to the category. From this it follows that natural kinds are more likely to figure in category-specific deficits. The other prediction that follows from OUCH is that various different patterns of category-specific deficits are expected to occur, reflecting the vagaries of the distribution of damage to the semantic space in different cases of brain damage. That is, because in this view the semantic system consists of a seamless, but lumpy space, the particular categories that are affected will depend on which specific regions of the brain are damaged. Thus, for example, OUCH does not exclude the possibility of a subject with disproportionate impairment to the category of living things, foods, musical instruments, and precious stones (as was the case for J.B.R., reported by Warrington & Shallice, 1984).

The other major prediction made by OUCH is that selective impairment of specific semantic categories should *not* be associated with disproportionate deficit to either visual or functional attributes of objects. This expectation is based on the fact that focal damage to the semantic system should affect closely correlated properties that are likely to involve both visual and functional attributes. This prediction clearly distinguishes the OUCH model from the SFT because, as we have seen, the latter theory of conceptual organization predicts the opposite result—namely, that category-specific deficits for living things should be associated with a disproportionate deficit for the visual attributes of objects.

The patterns of category-specific deficits reviewed here are consistent with expectations derived from OUCH. The model predicts the occurrence of category-specific deficits without postulating a categorical organization of semantic knowledge. It also allows for the existence of various combinations of category-specific deficits. And, finally, it is consistent with the results showing that category-specific deficits are not necessarily also modality-specific in nature (contrary to the prediction derived from the SFT). Thus, OUCH offers a better account than the SFT for the various empirical phenomena related to category-specific deficits.

Although OUCH can account for important aspects of the category-specific deficit phenomenon, it is unsatisfactory in at least one respect: It is too vague on critical issues about the nature and organization of semantic information, allowing it to account for almost any pattern of category-specific deficits. All it needs to do for

the latter purpose is to assume, for example, that brain damage has accidentally affected one of the lumpy regions of semantic space, thereby resulting in a category-specific deficit. Although this kind of explanatory power would be welcome in the context of an explicitly articulated theory of semantics, in the present case it merely reflects the unconstrained nature of the model's central assumptions. Furthermore, the model fails to provide a principled account for the patterns of attested forms of category-specific deficits. Specifically, the OUCH (just like the SFT) fails to explain *why* it is that by far the most prevalent form of category-specific deficit involves the category of living things.

Categorical Organization of Knowledge in the Brain: A Speculative Hypothesis

The reservations we have voiced about the reductionist accounts of category-specific deficits (the SFT and OUCH models) encourage us to explore the alternative hypothesis that semantic knowledge may be organized categorically in the brain (Warrington, 1981). The hypothesis we wish to entertain is that evolutionary pressures have resulted in specialized mechanisms for perceptually *and* conceptually distinguishing animate and inanimate kinds (R. Gelman, 1990; Premack, 1990), leading to a *categorical* organization of this knowledge in the brain. We will call this hypothesis the *domain-specific knowledge* hypothesis. In the "Discussion" section, we will elaborate further on this view and offer various arguments in its defense. Here we simply note that the hypothesis receives initial plausibility from developmental research, which has shown that infants as young as 3 months old are able to distinguish animate from inanimate objects, as indicated, for example, by their ability to distinguish biological from nonbiological motion (Bertenthal, 1993; Bertenthal, Proffitt, & Cutting, 1984) and their ability to distinguish caused from non-caused motion (Leslie, 1982, 1988; and see Leslie & Keeble, 1987, for results on 6-month-old infants) and that the 8- to 10-month-old infant's ability to distinguish animals from nonanimals is unlikely to be merely perceptually based (Quinn & Eimas, 1996) but is most likely conceptually driven (Mandler, 1992). Thus, for example, using a dishabituation paradigm, Mandler and McDonough (1993) have shown that 9-month-old infants dishabituate to an animal after repeatedly seeing models of a vehicle (and vice versa) even though the dishabituating stimulus may be highly visually similar to the habituated objects (e.g., birds and airplanes). These observations further encourage us to explore the possibility that a fundamental distinction in human knowledge—that between knowledge of animate and inanimate things—may be rooted in specific evolutionary adaptations.¹⁸

The domain-specific knowledge hypothesis makes the following two predictions about the nature of category-

specific deficits. First, the only "true" category-specific deficits are those involving categories of knowledge for which evolutionary pressures have led to the development of specialized neural mechanisms for their perceptual and conceptual distinction. Plausible categorical distinctions are those among animals, plant life, and artifacts.¹⁹ The other major expectation derived from this hypothesis is that (everything else being equal) category-specific deficits should result in comparable impairments for the visual and functional attributes of a concept. This prediction reflects the assumption that the category-specific nature of the deficit results from the fact that brain damage has affected a categorically organized knowledge system that represents all types of information relevant to that semantic domain.²⁰

The evidence on category-specific deficits that we have reviewed in the preceding sections is consistent with the expectations derived from the hypothesis that semantic knowledge is organized categorically in the brain, although it is also consistent with the OUCH model. Here we provide further experimental evidence for the hypothesis that semantic knowledge is organized categorically. We present a case study of a brain-damaged subject, E.W., who has a selective deficit for the category of animals and who is equally impaired for the visual and functional attributes of the members of this category. This pattern of performance—which is predicted by the domain-specific knowledge account—has not been reported previously. The results are organized as follows. First we show that subject E.W. is disproportionately impaired in naming animals relative to other living things and artifacts. We then show that this deficit is not merely due to a lexical retrieval problem because E.W. is also severely impaired in visually recognizing animals and in recognizing them from their characteristic sounds. Third, we show that E.W.'s deficit occurs at the conceptual level because she is not only impaired in processing pictures of animals but also in answering verbal questions about them. In this section we also show that her disproportionate semantic deficit for animals is equally severe for the visual and functional properties of members of this category.

RESULTS

Does E.W. Have a Category-Specific Naming Deficit?

Naming the Snodgrass and Vanderwart Pictures

The first analysis of E.W.'s performance is directed at establishing that E.W. has a category-specific naming deficit. Naming performance is summarized in Table 1. A response was considered correct if E.W. provided the Snodgrass and Vanderwart (1980) name or any acceptable response produced by the control subjects ($n = 5$). For both the control subjects and E.W., performance is broken down by animacy and familiarity. Familiarity was

Table 1. Snodgrass and Vanderwart Naming Performance (proportion correct, range = # correct)

<i>E.W.</i>	<i>Animal</i>		<i>Nonanimal</i>	
High familiarity	6 of 11 (0.54)		170 of 181 (0.94)	
Low familiarity	10 of 36 (0.28)		18 of 22 (0.81)	
<i>Control subjects</i>	<i>Animal</i>		<i>Nonanimal</i>	
	<i>Mean</i>	<i>Range</i>	<i>Mean</i>	<i>Range</i>
High familiarity	11 of 11 (1.0)	11	179 of 181 (0.99)	177-181
Low familiarity	34.2 of 36 (0.95)	31-36	21.8 of 22 (0.99)	21-22

Note: *n* = 250 total items. Ten items were removed from the set due to lack of consistency in responding by the control subjects (see “Methods”).

divided on the basis of the ratings provided in Snodgrass and Vanderwart, where familiarity was rated on a 5-point scale with 1 being very unfamiliar and 5 being very familiar. High-familiarity items were defined as those items with a familiarity rating greater than 2.5, and low-familiarity items were defined as those items with a familiarity rating less than or equal to 2.5. Note that this is a general breakdown by familiarity, and the number of items in each cell differs greatly. The mean familiarity for high-familiarity animate and inanimate items is 3.22 and 3.73, respectively. The mean familiarity for low-familiarity animate and inanimate items is 2.02 and 2.13, respectively.

Control subjects performed quite well and showed no effect of either semantic category or familiarity. However, E.W. demonstrated significant difficulties naming animals as compared to nonanimals ($z = 8.11, p < 0.05$). Although she does demonstrate more difficulty naming low-familiarity items overall ($z = 3.49, p < 0.05$), note that the low-familiarity nonanimal items are named at a much higher rate than high-familiarity animal items ($z = 2.60, p < 0.05$). This is not the case for the control subjects.

E.W.’s performance was not only significantly different on animal pictures compared to pictures from many other semantic categories, but the nature of her errors was qualitatively different as well. In the majority (34 of

47) of cases with animals, E.W. either said, “I have no idea what that is” or produced a semantically related response (Zebra → Gorilla, I think, but I’m not sure). By contrast, she only produced 5 of 137 semantic or “don’t know” responses to items in other semantic categories. For the latter categories most of her errors (12 of 137) were semantic descriptions followed by the comment, “Oh, what is that called?” Thus, for animals she often had no idea what the correct name of the picture was (i.e., she didn’t recognize the picture or she named it incorrectly), whereas for other categories she clearly recognized the picture but could not produce the name.

Controlling for Nuisance Variables in the Naming Task

As noted in the “Introduction,” it has been shown that when certain stimulus factors are carefully controlled, putative cases of category-specific deficit may turn out not to have such a deficit after all (e.g., Stewart et al., 1992). It is important, therefore, to carefully control for possible nuisance factors that may be responsible for a supposed semantic category effect. We carried out several tests to ensure that the noted effect for E.W. could not be ascribed to some such nuisance variable.

Table 2 presents an examination of E.W.’s naming

Table 2. Naming Performance on a Subset of Snodgrass and Vanderwart Pictures Based on Familiarity and Frequency (proportion correct)

	<i>Low familiarity/low frequency</i>		<i>Matched: familiarity and frequency^a</i>	
	<i>Animals</i>	<i>Nonanimals</i>	<i>Animals</i>	<i>Nonanimals</i>
E.W.	8 of 24 (0.33)	16 of 24 (0.67)	12 of 22 (0.55)	18 of 22 (0.82)
Controls	11.8 of 12 (0.98)	12 of 12 (1.0)	11 of 11 (1.0)	10.8 of 11 (0.98)
Range	11-12	12	11	10-11

Note: The items in this analysis were taken from Appendices 2 and 3 in Funnell and Sheridan (1992). They represent items from the Snodgrass and Vanderwart picture set that are either low familiar/low frequency items or are items matched on frequency. This was further broken down by animacy.

^aTwo items in this set (bee & violin) were removed because they were removed from the entire picture set.

Table 3. Naming Performance on a Subset of Snodgrass and Vanderwart Pictures Based on Visual Complexity and Visual Complexity/Familiarity (proportion correct)

	<i>Matched: Complexity</i>		<i>Matched: Complexity and familiarity</i>	
	<i>Animals</i>	<i>Nonanimals</i>	<i>Animals</i>	<i>Nonanimals</i>
E.W.	10 of 36 (0.28)	32 of 36 (0.89)	7 of 17 (0.41)	16 of 17 (0.94)
Controls	35.4 of 36 (0.98)	35.4 of 36 (0.98)	16.6 of 17 (0.98)	16 of 17 (0.94)
Range	35–36	35–36	16–17	16–17

Note: The items in this analysis represent a subset of items from the Snodgrass and Vanderwart picture set that are matched on visual complexity (mean = 3.76, *SD* = 0.51) or on visual complexity (mean = 3.83, *SD* = 0.44) and familiarity (animate: mean = 2.78, *SD* = 0.84; inanimate: mean = 2.64, *SD* = 0.84). This was further broken down by animacy.

performance on the items included in Funnell and Sheridan’s (1992) tests of naming performance as a function of animacy and familiarity (from their Appendixes 2 and 3). These items are all taken from the Snodgrass and Vanderwart picture set. The items in the first set are all low-familiarity/low-frequency items, and the items in the second set are matched on familiarity and frequency (i.e., represent a range of familiarity and frequency). Since the number of items is quite low, we have included E.W.’s naming performance from two administrations of the naming task. Control subjects only named the Snodgrass and Vanderwart picture set once.

It is immediately apparent that E.W.’s naming is affected by the animacy variable for both sets of items ($z = 2.92, p < 0.05; z = 2.85, p < 0.05$, respectively), even when those items have been controlled for familiarity. Thus, taken together with the above analyses, E.W.’s deficit in naming animals can be attributed to a deficit affecting the category of animals and not an artifact due to familiarity of the items.

However, Stewart et al. (1992; see also Gaffan & Heywood, 1993) argued that naming could also be influenced by visual complexity. Table 3 contains E.W.’s naming performance on a subset of items from the Snodgrass and Vanderwart picture set that are matched on visual complexity ($n = 36$) and a subset of items that are matched (as closely as possible) on *both* visual complexity and familiarity. Once again, it is obvious that

neither the factor of visual complexity nor the combined factor of visual complexity and familiarity is responsible for E.W.’s decrement in performance for animate items. Instead, E.W.’s picture-naming performance is influenced strongly by the factor of animacy and cannot be explained by extraneous factors such as familiarity or visual complexity ($z = 5.75, p < 0.05; z = 3.17, p < 0.05$, respectively).

The Naming Deficit Is Restricted to Animals and Is Not General to Living Things

A crucial part of this investigation involves determining the boundaries of the category-specific deficit. Specifically, we are concerned with determining whether E.W. is disproportionately impaired in processing living things or the more restricted category of animals. For this purpose we considered E.W.’s performance for specific semantic categories.

Table 4 provides a breakdown of E.W.’s naming performance according to specific semantic categories. Several things should be noted. First, E.W.’s naming performance is not affected by the category of *living* things but rather by the category of *animate* things. Thus, like several other reported cases (Farah & Wallace, 1992; Hart et al., 1985; Hillis & Caramazza, 1991), E.W.’s deficit respects a more fine-grained distinction than living/nonliving. Although performance broken down by

Table 4. E.W.’s Naming Performance as a Function of Specific Semantic Category (proportion correct)

<i>Category</i>	<i>Performance</i>	<i>Category</i>	<i>Performance</i>
Animal	16 of 47 (0.34)	Kitchenware	16 of 17 (0.94)
Body part	11 of 12 (0.92)	Musical instrument	8 of 10 (0.80)
Clothing	27 of 27 (1.0)	Tool	19 of 23 (0.83)
Fruit	12 of 12 (1.0)	Vegetable	12 of 12 (1.0)
Furniture	15 of 15 (1.0)	Vehicle	13 of 14 (0.93)
Other	53 of 61 (0.87)		

semantic category in this set of items must be interpreted with caution because the items in each of the categories are not controlled for potential nuisance variables (i.e., familiarity, frequency, and visual complexity), it is clear from Table 4 that E.W. is not impaired in naming fruits and vegetables: Her performance for fruits and vegetables was perfect (100%) and strikingly different from that for animals (34%).

E.W.'s Naming Deficit Is Not Restricted to Visual Stimuli: Sound Identification

In order to determine whether E.W.'s naming deficit might not reflect a category-specific visual agnosia, she was tested with a sound identification task in which the animal and nonanimal sounds were matched as well as possible on difficulty level as determined by the performance of several control subjects (see "Methods"). E.W. was quite poor at identifying animal sounds (8 of 32 = 0.25) as compared to nonanimal sounds (20 of 32 = 0.63), a difference that was significant ($z = 3.06, p < 0.05$). These results suggest that E.W. does poorly in naming animals across modalities (i.e., the deficit is not restricted to identifying and naming animals from pictures).

Summary

The results we have reported in this section show that E.W. has a semantic category-specific naming deficit. The deficit is restricted to the category of animals and not to the category of living things, as shown by the fact that naming of fruits and vegetables was virtually intact. E.W.'s poor naming performance for animals cannot be merely ascribed to nuisance variables such as familiarity and visual complexity since her disproportionate difficulties with animals persisted when these variables were strictly controlled. And, finally, E.W.'s naming deficit does not appear to be merely the result of a category-specific visual agnosia because she also showed disproportionately poor performance for animals in a sound identification task.

Does E.W. Have a Category-Specific Object Recognition Deficit?

Sartori and Job (1988; see also De Renzi & Lucchelli, 1994) reported that their subject Michelangelo, who showed a category-specific deficit for living things, was unable to distinguish between real and unreal animals and to decide which of four disembodied parts of an animal went with a body with a missing part. This type of performance has been interpreted as indicating a selective deficit for the visual properties of objects. However, not all cases of category-specific deficit are impaired in object decision tasks. There are several reports

of subjects with category-specific deficits for living things who perform within normal limits in object decision tasks (e.g., Laiacona et al., 1997; Sheridan & Humphreys, 1993). Thus, impairment in visual object decision performance is not a *necessary* feature of category-specific deficit for living things. It remains to be determined what implications follow from the association/dissociation of impairments at the level of object identification and naming. We will return to this issue in the "Discussion." Here we document that E.W. has a severe category-specific deficit in recognizing animals.

Object Decision Task

In this task, E.W. and two control subjects were asked to determine whether or not each picture represented a real object—either an animal or some type of artifact (see Figure 1). Performance for all subjects is summarized in Table 5. Normal control subjects performed fairly well on this task. E.W. had significant problems determining which pictures represented real animals (and there was a slight tendency to respond Yes in this task). Specifically, she was barely above chance level (60% correct) in distinguishing between real and unreal animals. She also had a few difficulties distinguishing between real and unreal artifacts (i.e., was willing to accept some unreal objects as real), but this is a problem shared by the control subjects and probably reflects the difficulty of the "unreal" inanimate objects. The important point is that E.W. performs poorly, and well outside the normal range, differentiating real and unreal animals but performs within normal range differentiating real and unreal objects.²¹

Part Decision Task

In this task, E.W. and two control subjects were asked to decide which of two "heads" went with a headless body (see Figure 2). E.W. was severely impaired at selecting the correct head for animals but not for artifacts (60% vs. 97%; $z = 3.45, p < 0.05$), and her performance with

Table 5. Object Decision Task (Hit = Real)

<i>Subject</i>	<i>Hit</i>	<i>Correct rejection</i>
E.W.:		
Animals	21 of 30 (0.70)	15 of 30 (0.50)
Nonanimals	30 of 30 (1.0)	25 of 30 (0.83)
Controls:		
Animals	29 of 30 (0.97)	25 of 30 (0.83)
Nonanimals	28.5 of 30 (0.95)	22 of 30 (0.73)

animals is not significantly different than chance ($z < 1$). Normal controls had no difficulty with either category (100% and 97% correct for animals and artifacts, respectively).

Summary

The results of the Object and Part Decision Tasks are clear: E.W. is severely impaired in discriminating between real and unreal animals but not between real and unreal artifacts. She is at chance in recognizing animals, but her performance with artifacts was indistinguishable from that of control subjects. This pattern of performance rules out the hypothesis that the locus of E.W.'s category-specific deficit is at the stage of name retrieval.

E.W.'s Category-Specific Object Recognition Deficit Is Not the Result of Impaired Visual Processing of Complex Objects.

The conclusion reached in the previous section regarding the locus of functional deficit in E.W.'s category-specific impairment may be challenged. It could be argued that the putative category-specific object recognition impairment for animals is merely the result of a generalized visual recognition deficit. On this view, the reason that E.W. shows a category-specific deficit for animals is because this category is perceptually more complex, in the sense that its members are more similar to one another than the members of other categories (e.g., Gaffan & Heywood, 1993; Humphreys & Riddoch, 1987). In order to rule out the possibility that E.W.'s difficulties in visually recognizing animals was the result of a general visual processing deficit, we tested her ability to perform difficult visual perceptual tasks.

Difficult Visual Matching and Categorization Tasks: The BORB

E.W. was administered those sections of the Birmingham Object Recognition Battery (BORB; Riddoch & Humphreys, 1993) that allow an assessment of her ability to perform complex visual matching and categorization tasks (see "Methods"). The tests (Tests 7, 8, 11, and 12) were administered in the standardized manner. She performed quite well and within normal range on all tasks.

Tests 7 (Minimal Feature Test) and 8 (Foreshortened View Test) of the BORB are complex visual processing tasks that involve matching a picture of an object seen from a "standard" viewpoint to the same object viewed from a different, nonstandard viewpoint. E.W. performed these tasks quite well. She scored 88% and 84% correct—well within normal limits. And she performed flawlessly in a similar task (Test 11: Object Matching Test) that required her to match an object (or a part of an object) to a different view of that object, and very well

(93% correct) in an association matching task that requires the semantic interpretation of pictured objects.

Face Recognition

E.W. was asked to name pictures of famous people using the Boston Famous Faces Task (Albert, Butters, & Levin, 1979). She was given unlimited time to respond. Across all the faces (across all decades and level of difficulty), she performed very well (30 of 56 correct) and within normal range for her age group. This result suggests that E.W. does not have a specific problem processing complex visual material, such as faces.

Summary

There are no indications in the results of our tests of E.W.'s visual processing performance that she has any impairment in visual recognition or categorization other than specifically for animals. These results invite the inference that E.W.'s impairment in visually recognizing animals is categorically based and most likely has the same cause as her naming deficit.

E.W.'s Category-Specific Deficit for Animals Is Not Modality-Specific.

To this point we have documented that E.W. has a selective deficit in naming and recognizing animals, and we have shown that the recognition impairment is unlikely to merely reflect a generalized visual processing defect. Here we provide direct evidence that her category-specific deficit has a conceptual basis because she is also impaired in verifying whether an animal has a particular property or attribute (e.g., Does a giraffe have four legs?). We also address directly the issue of whether E.W. has more severe difficulty in processing the visual/perceptual as opposed to functional/encyclopedic properties of animals. As noted in the "Introduction," the latter issue is crucial for distinguishing between the SFT and amodal theories of semantic representation.

Attribute Processing Task 1: Central Attributes

In this task, E.W. and control subjects were asked to decide whether an attribute statement about an object is true or false. In this and the following attribute tasks, only a subset of the total data was used so that items could be matched on familiarity (see "Methods" section for a description of the matching procedure). The patterns of performance on the total data set did not differ from the patterns reported here. Results for E.W. and control subjects ($n = 5$) are presented in Table 6. E.W. has severe difficulties making judgments about animals ($z = 5.39, p < 0.05$), independent of whether the statement involves perceptual or associative/functional infor-

Table 6. Central Attributes Judgment Task (proportion correct; range for control subjects)

<i>E.W.</i>	<i>Animals</i>	<i>Objects</i>
Visual/perceptual:		
True	38 of 59 (0.64)	54 of 59 (0.92)
False	26 of 39 (0.67)	37 of 39 (0.95)
Associative/functional:		
True	20 of 30 (0.67)	30 of 30 (1.0)
False	17 of 27 (0.63)	26 of 27 (0.96)
<i>Controls</i>	<i>Animals</i>	<i>Objects</i>
Visual/perceptual:		
True	0.92–0.98	0.92–1.0
False	0.85–1.0	0.86–1.0
Associative/functional:		
True	0.93–1.0	0.93–0.97
False	0.96–1.0	0.92–1.0

Note: On the rating scale, 1 = just guessing and 5 = extreme confidence. The mean (*SD*) visual/perceptual rating for true statements is 4.85 (0.22) and for false statements is 4.75 (0.31). The mean associative/functional rating for true statements is 4.92 (0.24) and for false statements is 4.88 (0.15).

mation ($z < 0.5$). Thus, she only responded correctly to 65% of the visual *and* the functional/associative attribute statements about animals. By contrast, her performance on inanimate objects was very good and fell within normal limits.

Attribute Processing Task 2: Food/Nonfood Animals

This task was designed to examine E.W.’s knowledge of animals that can be eaten (food animals, e.g., chicken,

pig, cow) and those that are not typically eaten (by people of her generation and cultural background) in the Unites States (nonfood animals, e.g., dog, horse, robin). The rationale was to examine her visual/perceptual and associative/functional knowledge of animals that might be more familiar to her (food animals), even though the animals in the “food” group were matched to the animals in the “nonfood” group on familiarity.

As shown in Table 7, E.W. had severe problems answering questions about animals, both for visual/perceptual and associative/functional information and for food and nonfood animals (all z ’s < 1). She performed perfectly, however, when answering the question concerning whether or not the animal is a food animal (the question about edibility was judged to be very easy by control subjects).

Attribute Processing Task 3: General/Specific Property Judgments

Some properties of a category are shared by all or most members of a category; others are specific to one or only a few members of the category. Those properties that are true of all members of the category may be more important or even essential for the inclusion of an object in a category, but they do not contribute to distinguishing among members of the category. Thus, for example, knowing that something has a mouth and eyes may be sufficient to classify it as an animal but will not help in deciding whether it is a canary or an eagle. By contrast the information that an object is about the size of a child’s fist and yellow may be insufficient to support a decision about whether or not it is an animal but provides sufficient information for distinguishing between an eagle or a canary. We will refer to the former knowledge as *general-attribute* and the latter as *specific-attribute* knowledge.²² An important question concerns the level of knowledge that is damaged in E.W. Is she equally impaired with general- and specific-attribute knowledge?

The motivation for this question springs in part from

Table 7. Food/Nonfood Animal Attributes Judgment Task (proportion correct; range for control subjects)

<i>Subject</i>	<i>Food Animal</i>	<i>Nonfood Animal</i>
E.W.:		
Visual/perceptual	27 of 41 (0.66)	26 of 41 (0.63)
Associative/functional	32 of 41 (0.78)	32 of 41 (0.78)
Controls:		
Visual/perceptual correct	0.83–0.93	0.85–1.0
Associative/functional correct	0.88–0.93	0.81–0.88

Note: On the rating scale, 1 = just guessing and 5 = extreme confidence. The mean (*SD*) visual/perceptual rating is 4.69 (0.38). The mean associative/functional rating is 4.72 (0.38).

Table 8. General/Specific Attributes Judgment Task (proportion correct; range for control subjects)

<i>Subject</i>	<i>General</i>		<i>Specific</i>	
	<i>Visual</i>	<i>Associative</i>	<i>Visual</i>	<i>Associative</i>
E.W.:				
Animals	130 of 130 (1.0)	129 of 130 (0.99)	74 of 100 (0.74)	115 of 150 (0.77)
Inanimate	60 of 60 (1.0)	75 of 75 (1.0)	100 of 100 (1.0)	149 of 150 (0.99)
Controls:				
Animals	-	-	0.92-0.94	0.85-0.98
Inanimate	-	-	0.87-0.93	0.82-0.88

Note: On the rating scale, 1 = just guessing and 5 = extreme confidence. The mean (*SD*) visual/perceptual rating is 4.91 (0.23). The mean associative/functional rating is 4.86 (0.23).

the observation that E.W. is quite capable of distinguishing animals from artifacts (though she cannot distinguish between real and unreal, but possible, animals). This raises the issue of whether her ability to categorize an object as “animal” also allows her to access general-attribute knowledge about animals. In the eventuality that she could systematically access such information, it would establish that she is not confused about what an animal is but only about detailed distinctions among category members. To test this possibility, E.W. and control subjects ($n = 2$) were asked to decide whether general- and specific-attribute knowledge statements about an object are true or false (see “Methods” for details). The results are shown in Table 8 and clearly demonstrate that E.W. has no difficulty with questions concerning attributes that are shared by all (or almost all) members of a category. Because of this, control subjects did not complete these questions. E.W. performed almost perfectly with specific-attribute information about inanimate objects (and better than both control subjects) and much worse with specific-attribute information for animate objects ($z = 4.69, p < 0.05$). Similar to the pattern of performance on the previous attribute judgment tasks, her knowledge of specific attributes of animals is equally disrupted for visual and for associative/functional information ($z < 1$).

Attribute Processing Tasks: Collapsing Across Tasks

The pattern of performance across the attribute judgment tasks reported thus far is clear: E.W. has severe

problems with the attributes of animate objects regardless of whether or not they relate to visual properties or to associative properties and has no problem with attributes of inanimate objects. For animals, the only questions on which she performs very well are general-attribute knowledge questions, indicating that she knows that animals have eyes and mouths and that they breathe and digest food, but little else besides that.

To examine further her performance with visual/perceptual and associative/functional information for animals and nonanimals, we collapsed her data across all the attribute judgment tasks. This gives us a very large number of data points in each cell, as well as a range of difficulty of questions. Performance is summarized in Table 9 for matched items. Although there is a small advantage for associative/functional information over visual/perceptual information for animals, this difference is far from significant ($z = 0.7974, p > 0.05$) and is only slightly larger than a similar difference for inanimate objects.

Attribute Processing Task 4: Shared Attributes

Although the evidence presented thus far on attribute judgments would seem to indicate that E.W. has a category-specific deficit for animals, there remains the possibility that the putative modality-specific nature of the deficit merely reflects a selective deficit in processing certain attributes that happen to be differentially distributed across semantic categories. That is, there is the possibility that the problem concerns the *properties*

Table 9. Matched Data Collapsed Across All Attribute Judgment Tasks (proportion correct)

	<i>Animals</i>	<i>Inanimate objects</i>
Visual/perceptual	202 of 301 (0.67)	217 of 226 (0.96)
Associative/functional	223 of 300 (0.74)	217 of 219 (0.99)

themselves and not the semantic category of animals. If that were the case, a category-specific deficit emerged only because we queried different properties for animals and nonanimals, and these properties just happened to be differentially damaged. To circumvent this potential problem, E.W. was tested in two attribute judgment tasks with the *same* attributes for animate and inanimate objects.²³

Attribute Processing Task 4a: Size Judgments. In this task, E.W. was asked to decide which of two animate or two inanimate objects is the larger of the two. Performance is summarized in Table 10 and demonstrates that E.W. had more difficulty with animal size judgments than inanimate size judgments ($z = 1.83, p < 0.06$) and is outside the normal range for the animal category but not the inanimate category.

Attribute Processing Task 4b: Other Shared Attributes. In this task, E.W. was asked to decide whether a property statement about animate and inanimate objects was true or false (see “Methods” for examples of the properties included in the task). Performance is summarized in Table 10 and indicates that E.W. had much more difficulty with attributes of animate items than those same attributes associated with inanimate items ($z = 3.38, p < 0.05$).

Attribute Processing Task 5: Visible and Not Visible Attributes

E.W.’s performance in the preceding two tasks shows that her deficit involves the category of animate objects and is not specific to attribute concepts found exclusively with animals. As a further test of her ability to process the attribute concepts that she is unable to verify in the context of judgments about animals, we asked her to answer questions about properties of pictured animals in one of two conditions: when the prop-

erties were visible and when they were not visible in the pictured animal. Thus, for example, E.W. was asked to decide whether a horse has a tail when shown a picture of a horse with a tail and when shown a picture of a horse from a perspective that did not show its tail. The crucial issue is whether she can answer attribute questions correctly when the information is available in the pictured object but answers incorrectly when the information is not given in the picture. E.W. had no problems (100% correct) answering the attribute questions when the information was available in the picture but had serious problems (55% correct) when the information was unavailable in the picture ($z = 7.28, p < 0.05$).

Summary

The results of the attribute processing tasks show that E.W.’s category-specific deficit extends beyond her naming and picture recognition difficulties to involve language comprehension. Her deficit appears to be conceptually based and is not just a deficit of visual perception or of lexical access in production. The results also clearly show that E.W.’s deficit involves equally the visual/perceptual and the functional/associative properties of animate objects. And, finally, her difficulties with object attributes are the result of a category-specific impairment for animate objects and not a generalized deficit for those attribute concepts. In short, the results show that E.W. has a *semantic* category-specific deficit.

DISCUSSION

The results we have reported can be summarized as follows:

1. E.W. has a category-specific deficit restricted to the category of animate objects: She is disproportionately impaired in naming animals relative to other living things, such as fruits and vegetables, and relative to all other inanimate categories tested, including food items. The category-specific nature of the deficit persisted under strict control of potential nuisance factors such as item familiarity, visual complexity, frequency, or their combination.
2. E.W. has a category-specific deficit in visually (and auditorily) recognizing animate objects: She is disproportionately impaired in recognizing animals relative to other living items and artifacts. This deficit is not the result of a generalized perceptual processing deficit interacting with differential levels of visual complexity across categories. E.W. performed within normal limits in complex visual processing tasks.
3. E.W. has a category-specific deficit in language comprehension. In various types of attribute processing tasks she performed very poorly with statements about animate objects but performed within normal limits with statements about other living things and artifacts. This

Table 10. Size Judgments Task and Matched Attributes Judgments Task (proportion correct; range for control subjects)

Size Judgments		
Subject	Animals	Inanimate
E.W.	13 of 18 (0.72)	17 of 18 (0.94)
Controls	0.94–1.0	0.94–1.0
Matched Attributes Judgments		
Subject	Animals	Inanimate
E.W.	32 of 42 (0.76)	42 of 42 (1.0)
Controls	0.94–0.97	1.0

Note: On the rating scale, 1 = just guessing and 5 = extreme confidence. The mean (SD) rating is 4.97 (0.09).

selective deficit persisted in the face of stringent controls of various nuisance variables.

4. E.W.'s category-specific deficit for animals is *not* also modality-specific (for visual knowledge). In various attribute processing tasks, she consistently performed equally poorly with visual and functional/associative statements of animate objects and equally well, and within normal limits, for all attributes of inanimate objects.

The facts 1 through 4 allow several conclusions about the nature of E.W.'s deficit. E.W.'s selective impairment in recognizing and naming animate objects is not restricted to the recognition of visually presented stimuli but extends to auditory stimuli as well, and the fact that her impairment extends to language comprehension tasks (facts 1 through 3) allows the inference that her deficit involves the semantic system and not simply the visual recognition or the word production systems. Fact 4—E.W.'s selective impairment concerning animate objects is equally severe for their functional/associative and visual attributes—allows the inference that the damaged system is not organized by “modality;” that is, the damaged system does not represent visual and functional/associative knowledge in distinct subsystems.

These conclusions have important implications for the issues raised in the “Introduction” concerning the organization of conceptual knowledge in the brain. First, they are at variance with the sensory/functional theory (SFT) of semantic category-specific deficits (Farah & McClelland, 1991; Silveri & Gainotti, 1988; Warrington & Shallice, 1984) and thus provide a clear refutation of this theory of semantic organization. Second, they are consistent with the hypothesis of amodal organization of the semantic system, as proposed by the organized unitary content hypothesis (OUCH; Caramazza et al., 1990). And, third, they encourage the hypothesis of domain-specific organization of knowledge in the brain. We discuss each of these issues in turn.

Refutation of the Sensory/Functional Theory of Category-Specific Deficits

The SFT makes two clear predictions concerning category-specific deficits. One prediction is that category-specific deficits should not honor “narrow” semantic category boundaries but should instead be determined by the role played by visual (sensory) features in determining the meaning of category members. This translates into the expectation that the categories of animals and fruits and vegetables (as well as other visually weighted categories) should be damaged together. The other major prediction is that category-specific deficits for living things should necessarily also be modality-specific, in the sense that knowledge of visual properties must be disproportionately impaired relative to knowledge of functional/associative properties. Neither prediction held up

in our investigation of E.W. Her category-specific deficit is restricted to the category of animals, leaving unaffected her knowledge of fruits, vegetables, and artifacts, and her knowledge of functional/associative attributes of animals is as impaired as her knowledge of their visual attributes.

Other results in the literature are highly problematic for the SFT. The case of selective *sparing* of the category of animals (Hillis & Caramazza, 1991) and of subjects with selective damage of the category of fruits and vegetables (Farah & Wallace, 1992; Hart et al., 1985) complement the results reported for E.W. (which show that she has a selective deficit for animals). These results jointly establish that category-specific deficits can be very narrow, involving separately the categories of animate objects and the category of fruits and vegetables, thus undermining the expectation derived from the SFT that the categories of living things should be damaged together. The other set of results that converges with E.W.'s performance in undermining the SFT concerns reports of subjects with category-specific deficits for living things who do not show a disproportionate deficit for visual attributes of living things (Funnell & De Mornay Davies, 1997; Laiacona, Barbarotto, & Capitani, 1993; Laiacona et al., in press; Sheridan & Humphreys, 1993). Thus, on this issue too, there is no support for the SFT.

There remain two other sources of evidence that have been cited in support of the SFT—the results of some neuroimaging studies (e.g., Martin, Wiggs, Ungerleider, & Haxby, 1996) and the results of computational modeling (Farah & McClelland, 1991). We will discuss the neuroimaging results in greater detail in a later section. Here, it suffices to say that some of the neuroimaging results are consistent with the SFT, but they are also consistent with alternative interpretations. Thus, these results do not help distinguish between alternative theories of semantic organization. We begin with a discussion of the putative evidence from computational modeling.

Farah and McClelland (1991) purport to show that damage to the visual component of a modality-organized semantic system can explain the existence of category-specific deficits. They did this by developing a parallel distributed processing (PDP) model in which semantic knowledge is subdivided into visual and functional components. The two major assumptions of this model are that visual and functional semantic properties are represented in separate but interconnected networks and that the ratio of visual to functional properties for living things is much larger than that for nonliving things. When the visual components of various networks implementing these assumptions were lesioned, the resulting patterns of performance mimicked the category-specific deficit for living things, and the reverse dissociation was obtained when the functional component of the network was lesioned. This pattern of results provides an existence proof that a category-specific deficit can be

obtained without having to postulate categorical organization of semantic knowledge.

As an existence proof that category-like effects can emerge from a noncategorically organized semantic system, the results reported by Farah and McClelland (1991) need not be controversial, nor even surprising for that matter. In some respects the results of the implemented model merely reflect their assumption that the meaning of living things is much more dependent on visual properties than is the case for nonliving things.²⁴ In their modeling experiments, the ratio of visual to functional properties for living things was set to 16.1:2.1, and for nonliving things it was set to 9.4:6.7. Thus, damage to the visual semantic network could hardly result in anything but more severe difficulty for living than nonliving things. Put differently, the highly disproportionate ratios of visual to functional properties for the categories of living and nonliving things can be seen as roughly approximating a categorical distinction between the two semantic domains. The model merely capitalizes on this correlation. As noted by Farah and McClelland (1991), "The ability of a modality-specific semantic memory architecture to account for category-specific semantic memory impairments depends, of course, on there being a correlation between modality of knowledge and category of knowledge" (p. 355). If there were no such correlation, it would not be possible to devise a modality-based explanation for category-specific deficits. Thus, the ultimate value of the modeling demonstration depends entirely on the validity of the empirical assumptions made by the model, that is, the assumptions about the ratios of visual to functional properties for the living and nonliving categories, respectively.

Warrington and her collaborators (Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984) had suggested that living things are known and distinguished primarily through their visual attributes, whereas nonliving things are known primarily through their functional/associative properties. This suggestion was based on mere intuition; however, Farah and McClelland (1991) attempted to provide an empirical foundation for this intuition. They did this by counting the number of visual and functional descriptors that subjects identified in dictionary definitions of the living and nonliving things used by Warrington and Shallice (1984, Experiment 2). They found that subjects underlined more visual descriptors for living than nonliving things (an average of 2.68 and 1.57, respectively) but many fewer functional descriptors for living than nonliving things (an average of 0.35 and 1.11, respectively). Thus, the ratio of visual to functional properties was found to be far higher for living (7.7:1) than nonliving things (1.4:1). These results seem to confirm the speculation about the relative importance of visual and functional-associative properties in determining the meaning of living and nonliving things. However, there is a serious flaw in the experimental procedure used by Farah and McClelland that makes

interpretation of their results problematic at best. The problem concerns the instructions given to subjects on what to count as visual and functional-associative descriptors.

Farah and McClelland (1991) asked their subjects to underline either visual or functional descriptors in definitions of living and nonliving things. Subjects in the visual descriptor condition were asked to underline all words referring to the visual appearance of an item. Subjects in the functional descriptor condition were asked to underline "all occurrences of words describing *what the item does or what it is for*" (p. 342; emphasis added). Now, it is clear that all objects, living and nonliving, can be described by reference to their visual appearance and, therefore, counting the visual descriptors in definitions of items in the two categories may provide a fair estimate of the *sensory properties* known by subjects about various objects. However, asking subjects to underline "what it is for" for living and nonliving things will not provide a fair estimate of the *nonsensory properties* known for living things. That is, because the use of an item—what it is for—is a highly specific property typically found with artifacts but not natural kinds, having a "function" is almost a distinguishing feature between living things and artifacts. It is meaningful to ask "What is a table or a knife for?" but barely felicitous to ask "What is a lion or a squirrel for?" Thus, it is hardly surprising that Farah and McClelland found large discrepancies in the ratios of visual to functional descriptors for living and nonliving categories; these discrepancies are entirely due to the instructions given to subjects on what could count as a functional/associative feature. We can easily imagine reversing the ratios of visual to functional properties for living and nonliving things by instructing subjects to underline visual properties that are found almost exclusively in nonliving things, such as "has wheel-like features," "has straight edges," "has wood-like texture," and so on. In this case, we would most likely find that nonliving things would have a larger ratio of visual to functional/associative attributes than living things.

It is crucial that the criteria for identifying the sensory and nonsensory properties of living and nonliving things not contain a built-in category bias. However, the instructions Farah and McClelland (1991) gave their subjects effectively led them to exclude from consideration such important nonsensory properties of living things as "lives in desert," "ferocious," "carnivore," "herbivore," "domesticated," "solitary," "edible," "egg-laying," and so on. If these and other nonsensory properties had not been excluded by the instructions biasing subjects to consider only "what it is for"—principally a property of artifacts—the differences in the ratios of sensory to nonsensory properties for living and nonliving things would not have been nearly as large as reported by Farah and McClelland. Indeed, when we instructed two groups of subjects to underline either all sensory properties or all non-

sensory properties in the definitions of the living and nonliving items used by Farah and McClelland,²⁵ we obtained the following ratios of sensory to nonsensory properties for living and nonliving things: 2.9:2.5 and 2.2:2.3 respectively.²⁶ Similar results have recently been obtained by McRae, de Sa, and Seidenberg (1997) using a different procedure to estimate the ratio of visual to functional attributes for living and nonliving categories. These ratios do not provide empirical support for the assumption that there is a correlation between “modality of knowledge and category of knowledge.”²⁷

In this section we have argued that neither of the major expectations derived from the SFT—the predicted correlation of category deficits and the predicted co-occurrence of category- and modality-specific deficits—receives support from E.W.’s performance or the performance of other reported cases of category-specific deficit. We have also argued that the computational modeling evidence (Farah & McClelland, 1991) offers no more than an existence proof that category-like effects can result from damage to noncategorically organized subsystems whose contents are correlated with semantic categories. However, the success of the computational modeling demonstration does not require that the contents of the subsystems be modality-specific. All that it requires is that there be a correlation between the contents of specific subsystems and semantic categories. The contents of subsystems can vary from completely nonoverlapping (categorical) representations to modality-specific subsystems that are correlated with different semantic categories (SFT) to modality-neutral clumps of intercorrelated semantic properties that are correlated with different semantic categories (OUCH). Thus, the computational modeling demonstration reported by Farah and McClelland would only be useful in distinguishing between the SFT and alternative accounts of category-specific deficits if its assumptions about the contents of the hypothesized subsystems could be motivated empirically. However, we have argued that the empirical evidence provided by Farah and McClelland for a putatively large discrepancy in the ratios of visual to functional/associative properties for living and nonliving things is tainted by having inappropriately restricted what could count as a functional/associative attribute (because only “what is it for” attributes were allowed, favoring the kinds of attributes that artifacts, but not animals, are likely to have). And we have gone on to show that the ratios of visual to functional/associative properties for living and nonliving things are, in fact, approximately equal when subjects are instructed to count all perceptual and all nonperceptual (functional/associative) descriptors. Thus, the central assumptions about the nature of the semantic subsystems in the model proposed by Farah and McClelland are without empirical foundation, thereby undermining the value of the computational modeling demonstration as evidence in support of the SFT.

The Organized Unitary Content Hypothesis Revisited

The organized unitary content hypothesis (OUCH) makes two clear predictions: Category-specific deficits can be narrower than the living/nonliving distinction and category-specific deficits are not also modality-specific. E.W.’s performance is in agreement with both predictions from the OUCH: (1) Her deficit is restricted to the category of animate things, and (2) she is equally impaired in processing the visual and functional/associative attributes of animals and of no other semantic category. The model’s major drawback is that OUCH does not provide a principled explanation for the attested patterns of category-specific deficits: It fails to explain why the unambiguous cases of category-specific deficit seem to respect the tripartite distinction animal/plant/artifact (and not some other pattern of category-specific deficits—i.e., why not a selective deficit for aquatic animals) and why the most prevalent category-specific deficit involves the category of animals. Thus, although OUCH may provide a useful noncategorical framework within which to explore various aspects of semantic memory deficits, including their category-specific form, we may have to consider a radically different theoretical framework to explain the high prevalence of selective deficits for animals and the tripartite distinction animal/plant/artifact in the occurrence of category-specific deficits.

Domain-Specific Organization of Conceptual Knowledge in the Brain: Evolutionary Adaptations?

None of the evidence reviewed here, including E.W.’s performance, compels us to adopt the view that conceptual knowledge is organized categorically in the brain. However, doing so provides a natural explanation for precisely that feature of the phenomenon of category-specific deficits that has proven to be most problematic for the reductionist accounts: the fact that the categories of animals, fruits and vegetables, and artifacts can be damaged independently of each other. On this view, the empirically observed tripartite distinction of category-specific deficits follows directly from the assumption that these, and only these, three categories form the basis for the organization of conceptual knowledge. But the explanatory power of this assumption would amount to naught unless it could be given independent theoretical and empirical justification. That is, unless we can independently motivate the assumption of categorical organization of conceptual knowledge, we would have merely assumed what we are trying to explain—an infelicitous circularity. It is important, therefore, to determine whether there might not be theoretical arguments and empirical evidence that could be used to independently

support the assumption that conceptual knowledge is organized categorically.

In the "Introduction" we speculated that adoption of an evolutionary perspective to the problem of how conceptual knowledge is organized in the brain might provide the motivation for assuming that it is organized categorically. It is not implausible to assume that evolutionary pressures led to specific adaptations for recognizing and responding to animal and plant life (the latter operationally represented by fruits and vegetables in research on category-specific deficits). The fitness value for these adaptations are obvious: Animals are potential predators but also a potential source of food; plants are a source of food and medicine. The ability to recognize and respond quickly to types of animals has clear survival and reproductive value, as does the ability to accurately distinguish among different plants for their alimentary and medicinal value. In perceptual and cognitive terms, these adaptations might consist of specialized processes for the rapid and accurate classification of objects as animals, as plant life, or as neither of these two categories of objects. In terms of neural mechanisms, the relevant adaptations might consist of dedicated neural circuits for processing animals and plant life. And because of the clear affective/emotional component associated with flight and feeding responses to animals and plant life, it is not implausible to further assume that the neural adaptations would involve circuits that include the limbic system. If these speculations were to be even approximately correct, we would have the independent motivation we have been seeking in support of the assumption that conceptual knowledge is organized categorically in the brain. The evolutionary adaptations for recognizing animals and plant life would provide the skeletal neural structures around which to organize the rich perceptual, conceptual, and linguistic knowledge modern humans have of these categories.

An important implication that follows from the adoption of an evolutionary perspective on the organization of conceptual knowledge in the brain is a restriction on what is likely to count as evolutionarily significant semantic categories—that is, categories for which it is plausible to propose that their successful recognition would have fitness value. We have argued that animals and plant life satisfy the latter criterion. Whether or not the ability to recognize and use "tools" should also be accorded fitness value is less obvious, although not implausible (see Hauser, in press). However, it is not necessary that tools be accorded such status for the argument developed here. It is sufficient that the categories of animals and plant life be distinguished from "other" categories. Thus, on this view, the only "true" category-specific deficits²⁸ will be those involving the categories of animals, plant life, and (by contrast) artifacts and not other finer-grained distinctions such as land animals, fruits, kitchen utensils, and so on.

Another implication that follows from the assumption

that evolutionary adaptations provide the basis for the categorical organization of conceptual knowledge in the brain is that the incidence of category-specific deficits for living things should be greater than that for nonliving things. This implication is derived from the supposition that specialized neural mechanisms are more likely to be highly localized and consequently more prone to selective damage. This expectation would seem to have some support. Most category-specific deficits that have been reported over the past 15 years have involved the categories of living things. Of course, it could be that some of the putative category-specific deficits for living categories are merely artifacts of inadequate stimulus controls (Stewart et al., 1992; Funnell & Sheridan, 1992). However, as discussed extensively in the "Introduction," there is now a substantial number of well-studied cases of category-specific deficits for living categories that cannot be dismissed as methodological artifacts (see, for example, cases in Laiacona, Barbarotto, & Capitani, 1993; Laiacona et al., 1997). Thus, even with a major correction for possible methodological artifacts in the early studies of category-specific deficits, the discrepancy between the incidence of selective impairment for the living and nonliving categories remains striking.

A further implication of the view that there might be dedicated neural circuits for the categories of animals and plant life involves the category of foods. Because the assumed neural circuitry for animals and plant life involves the limbic system, it is not unreasonable to suppose that the semantic category of foods might share some of its neural circuitry. Consequently, damage to neural structures that affect the categories of animals or of fruits and vegetables are also likely (though not necessarily) to result in impairment of the category of foods, even though many members of the latter category are more properly considered artifacts (consider, for example, spaghetti, fudge, hamburger, and so on). This assumption would explain why some cases of category-specific deficits for living categories also show impairments for foods.

The hypothesis that knowledge is organized categorically in the brain provides a good account of extant results on semantic category-specific deficits. However, it is important to stress here that the appeal to evolutionary pressures as a possible causal basis for the categorical organization of knowledge in the brain is not necessarily incompatible with the cognitive principles that characterize the OUCH and SFT proposals. Indeed, it is quite likely that both domain-specific and domain-general learning principles are involved in the organization of conceptual and linguistic knowledge in the brain. The domain-specific principles have a very narrow range of applicability and serve only to explain why it might be the case that knowledge of animals and of plant life is represented in distinct neural circuits. This account is silent on the larger issue of how conceptual knowledge *within* the broad categories of living and nonliving

things is organized. And it could very well turn out that domain-general principles such as those invoked under OUCH (or SFT, although no empirical support has been found for this account) provide the basis for the organization of conceptual knowledge *within* the distinct categories of animals, plant life, and artifacts.

Domain-Specific Organization of Conceptual Knowledge in the Brain: Ontogenetic Considerations

The idea that neural adaptations are responsible for the organization of conceptual knowledge in the brain has direct implications for theories of acquisition of this knowledge. Specifically, this thesis implies that there should be specialized mechanisms for the recognition and categorization of the members of the categories for which specific adaptations have evolved. And, in fact, the contrasting viewpoints about the possible bases for the existence of semantic category-specific deficits have their counterparts in the developmental literature. There the issue has been framed in terms of whether cognitive development is to be understood as the product of domain-general or domain-specific processes. The domain-general view holds that a common set of very powerful learning mechanisms underlies the acquisition of all forms of knowledge: from mathematical to musical skills and from language to the ability to play backgammon. This position is most clearly represented by the classical empiricist theories of learning and memory (e.g., Skinner, 1957) and more recently by connectionist theories (e.g., McClelland & Rumelhart, 1986). The domain-specific view holds that highly specialized, dedicated mechanisms are involved in the acquisition of specific types of knowledge (Carey, 1985; Pinker & Bloom, 1990; Sperber, 1994). The best-known domain-specific theory is the theory of universal grammar of language acquisition proposed by Chomsky (1980, 1986). However, domain-specific theories have also been proposed for speech perception (Liberman & Mattingly, 1989), naive physics and psychology (Carey & Spelke, 1994), number (Carey & Spelke, 1994; R. Gelman, 1990), the animate-inanimate distinction (R. Gelman, 1990), folk biology (Atran, 1995; Sperber, 1994), and, more generally, various aspects of animal learning (Rozin & Schull, 1988). In each case, it could be proposed that specialized cognitive mechanisms, reflecting adaptations in response to evolutionary pressures, are responsible for the acquisition of a specific type of knowledge (for recent reviews see papers in Hirschfeld & S. Gelman, 1994; Sperber, Premack, & Premack, 1995).

Of particular relevance here is the proposal that the acquisition of the animate-inanimate distinction involves domain-specific mechanisms. Although alternative proposals have been offered concerning the precise nature of the content of the domain-specific mechanism for acquiring the animate-inanimate distinction (see Atran,

1995; Carey, 1985; 1995; R. Gelman, 1990; R. Gelman & Brenneman, 1994; R. Gelman, Durgin, & Kaufman, 1995; Keil, 1994; Sperber, 1994), they all maintain that a set of innate principles guides its acquisition. These principles do their work by specifying the core content of the two categories. Their major function is to direct attention to the relevant exemplars of the categories by focusing on the salient distinctions among them. Candidate features of the environment that could serve the function of “triggering” a first-pass distinction between categories include the motion patterns of objects and their physical appearance (Mandler, 1992). However, the perceptual distinctions are not themselves criteria for distinguishing between categories. They merely function as cues to category membership. The categorical distinction is fundamental and precedes the acquisition of specific perceptual facts about their members. In other words, the perceptual features of objects are powerful cues to sameness of category, but they do not constitute the core properties of the animate-inanimate distinction. The latter are more likely to be complex properties that do not correspond to any simple perceptual feature. Thus, candidate core properties for animate objects might be their internal structure (e.g., having organs), whether they are capable of self-initiated motion, and whether their motion patterns can be construed as having intentional cause (Premack, 1990); for artifacts, a core property might be their intended function (Bloom, 1996).

There is considerable evidence in favor of the domain-specific thesis of the acquisition of the animate-inanimate distinction. Perhaps the most compelling results are those concerning the infant's ability to distinguish physical from psychological (biological) causality. Recent experiments have shown that infants as young as 3 months understand many aspects of the structure of the physical world. For example, they understand some of the distinguishing properties of the concepts of solidity and support, and they understand that two objects cannot occupy the same space at the same time (Baillargeon, 1993; Spelke, 1988). Furthermore, this knowledge is embedded in a larger conceptual scheme that involves object motion and the concept of causality. Spelke, Phillips, and Woodward (1995) have identified a set of core principles about the infant's understanding of objects—the principles of cohesion, continuity, and contact—which function to constrain the interpretation of an object's motion. For example, the principle of contact underlies the infant's understanding that objects can only act on each other by touching. There is a large body of evidence that very young infants understand the distinction between caused and uncaused motion through the principle of contact. Thus, 4-month-old infants can distinguish between the implicit causality in a ball's motion when it is launched by another moving object and the very similar, but fundamentally different, case where the two objects are separated either by a brief temporal lag or by a small spatial gap (Leslie, 1982, 1984;

Leslie & Keeble, 1987). These results, together with other recent evidence that shows that infants suspend application of the contact principle when reasoning about human (and perhaps animal) actions (Spelke et al., 1995), suggest that they are able to distinguish correctly between animate and inanimate objects (for otherwise they would not know when to apply and when to suspend the contact principle). More generally, it has been supposed that a core property of the infant's concept of human (and perhaps animal) is the principle of "self-propelled motion"—a concept intimately related to the distinction between mechanical and intentional agency (see R. Gelman, 1990; Premack, 1990; Mandler, 1992).

There are two other important sources of evidence in support of the infant's precocity in distinguishing animate from inanimate objects. One is the infant's well-documented ability to distinguish biological from nonbiological motion. Bertenthal and his collaborators (Bertenthal, 1993; Bertenthal, Proffitt, & Cutting, 1984) have shown that infants as young as 3 months can reliably distinguish point-light displays of motions produced by animate and inanimate objects. The other evidence concerns the infant's ability to categorize static representations of objects (toy figures and pictures). Mandler and her collaborators (Mandler, 1992, 1994; Mandler, Bauer, & McDonough, 1991; Mandler & McDonough, 1993) have shown that 9-month-old infants can distinguish between animals and vehicles even when between-category similarity is controlled. Using a dishabituation paradigm, they have found that infants dishabituate to airplanes but not dogs, cats, or rabbits after seeing birds even though birds were shown with outstretched wings and thus were more "perceptually similar" to airplanes than they were to dogs, cats, or rabbits. This pattern of results suggests that infants make a global differentiation between animals and artifacts before they fully appreciate the basic-level categories within these conceptual domains (but see Quinn & Eimas, 1996 for a different interpretation). Thus, the evidence from infants' precocious categorization of animate and inanimate toy objects as well as the evidence from their precocious distinction of point-light displays of animate and inanimate motion suggest that the distinction may be subserved by specialized domain-specific mechanisms.

In this section we have argued that recent developments in the area of concept acquisition provide important converging evidence for the proposal that conceptual knowledge is organized categorically in the brain. The evidence confirms the expectation derived from the claim that evolutionary adaptations form the basis for the hypothesized categorical organization of conceptual knowledge—namely, that the concepts of animal and artifact are acquired through the operation of innate domain-specific mechanisms.

Neuroanatomical Considerations

The neuroanatomical basis for semantic category-specific deficits has been addressed both through anatomo-clinical correlations and through functional imaging of the intact brain. The investigation of anatomo-clinical correlations has produced relatively clear though not unequivocal results. The picture is clearest for cases of selective deficit for living things. Most of these cases have sustained damage to the left temporal lobe (as well as the right temporal lobe in patients recovering from herpes simplex encephalitis; see Gainotti, Silveri, Daniele, & Giustolisi, 1995; Saffran & Schwartz, 1994, for reviews). However, some of the patients with disproportionate deficit for living things have also sustained damage to frontal and to inferior parietal areas (the case reported here; Hillis & Caramazza, 1991; Laiacona, Barbarotto, & Capitani, 1993) or extensive damage due to trauma (Farah et al., 1989; Laiacona, Barbarotto, & Capitani, 1993). The pattern of anatomo-clinical correlations is less clear for cases of selective impairment to the category of artifacts. Lesions associated with the latter pattern of deficit have been more variable and have typically included fronto-parietal areas but also the temporal lobe in some cases (for reviews see Gainotti et al., 1995; Saffran & Schwartz, 1994). A rough generalization from this literature is that the categories of living things are associated with temporal and sometimes frontal and parietal lobe lesions, whereas impairment of the category of artifacts is associated with more dorsal lesions involving temporal, parietal, and frontal areas.

Most cases of category-specific deficits have been interpreted as involving damage to the semantic system, allowing inferences about the possible organization of semantic knowledge in the brain. An alternative proposal has been offered by Damasio et al. (1996), who reported the most extensive investigation of the neuroanatomical basis for category-specific deficits to date. These investigators argued that category-specific naming deficits need not result from damage to the semantic system but can result from damage to the lexical representations mediating between the semantic and the phonological content of words. On this view, the analysis of patterns of category-specific deficits can inform hypotheses about the organization of lexical (as opposed to semantic) knowledge in the brain. In their investigation of a large number of patients with single, focal lesions who showed category-specific deficits ($N = 30$), Damasio et al. found that impairment for the category of animals is associated with damage to the left inferotemporal (mostly anterior) area, and impairment for tools is associated with damage to the posterolateral inferotemporal area and the junction of temporo-occipital-parietal cortices. Thus, despite differences in the functional interpretation of category-specific deficits,²⁹ the results of this

study further confirm the important role of the left temporal lobe in the representation of knowledge about the category of animals and the role of more dorsal areas for artifacts.

The results from functional neuroimaging experiments are somewhat unclear. Three PET studies have directly compared performance for living things and artifacts (Damasio et al., 1996; Martin et al., 1996; Perani et al., 1995). All three studies show segregation between categories, but the specific areas involved differ across studies. For the living things category, Perani et al. and Martin et al. found activation of the occipital lobes bilaterally and the inferior temporal lobe (bilaterally by Perani et al.; left only by Martin et al.). For the artifact category, Perani et al. found mostly left-sided activation of the lingual, parahippocampal gyri, middle occipital gyrus, and dorsolateral frontal regions; Martin et al. found activation of the fusiform gyri of the temporal lobes, bilaterally, and left inferior frontal region and left precentral gyrus. By contrast, Damasio et al. (whose study focused on activations of regions of the temporal lobe) found that naming animals resulted in activation of the left inferotemporal area, and naming of tools resulted in activation of posterior middle and inferior temporal gyri. Thus, there is some agreement among the three studies: The inferior temporal lobe is activated in processing animals; the posterior middle temporal area may be more important for tools. In addition, there are indications that the frontal lobes may be important not only for tools (Martin et al. and Perani et al.) but also for animals (Martin et al.). Finally, animal naming more strongly activates the occipital lobes, bilaterally.

It is not implausible, then, to conclude that the left temporal lobe is crucially involved in some aspect of lexical-semantic processing, as may be parts of the left frontal lobe. Although Damasio et al. (1996) interpret the function of the different areas of the left temporal lobe activated in naming animals and artifacts as involving mechanisms of lexical retrieval as opposed to semantic knowledge, this conclusion is premature at best (see Note 29). A more problematic issue concerns the interpretation of the differential roles of the occipital lobes in naming animals and artifacts. The interpretation proposed by Martin et al. (1996) is that because animals are visually more complex, there is a "top-down" modulation of visual processing to help visual identification. Whether or not this interpretation is correct, there are no reports of either category-specific recognition or category-specific semantic deficits following lesions of the left extrastriate cortex. Thus, the relevance of the observation that the occipital lobes are more intensely activated in naming animals as opposed to artifacts for issues about semantic processing remains obscure. What is clear, however, is that different neural mechanisms are involved in processing the categories of animate and inanimate objects.

Category-Specific Organization: Conceptual, Perceptual, or Both?

A final issue that needs to be addressed here is the relation between object recognition and semantic category-specific deficits. Sartori and Job (1988) were the first to report that a patient with a semantic category-specific deficit was unable to distinguish between real and chimeric animals. E.W. also showed marked difficulties distinguishing between real and unreal animals. However, the association of a category-specific deficit in object decision tasks with category-specific difficulties in lexical processing tasks is not a necessary one. There are reports of patients who show category-specific deficits in naming and comprehension tasks but who are fully able to distinguish real from unreal animals (e.g., Laiacona et al., 1997; Sheridan & Humphreys, 1993). Thus, category-specific object decision deficits dissociate from category-specific comprehension performance. A possible implication of these facts is that the category-specific organization of conceptual categories occurs at multiple levels of processing. Specifically, it could be argued not only that the conceptual system is organized categorically but also that the object recognition system is sensitive to category distinctions. In other words, category-specific specialization may be found at both cognitive and perceptual processing levels. This conclusion accords well with the view that the categorical organization of conceptual knowledge in the brain reflects a neural adaptation in response to evolutionary pressures. With this view, the fitness value of the proposed categorical distinction would depend in large measure on our ability to successfully make the correct perceptual distinctions. It would be advantageous, therefore, for specialization to occur as early as possible in the object recognition system.³⁰

Conclusion

We have reported the detailed analysis of the performance of a brain-damaged subject with a clear-cut category-specific deficit. Two features of this subject's performance are of crucial interest: The deficit was restricted to the category of animate objects, and it involved equally visual and functional/associative knowledge of animals. This pattern of performance is highly problematic for the sensory/functional theory of category-specific deficits. We have also shown through a critical review of the literature on category-specific deficits that the SFT is without empirical support. Instead, the evidence is consistent with the OUCH model, which maintains that categorical organization in the semantic system emerges from the correlational structure of the properties of members of a category. However, we have also argued that the results invite the more intriguing hypothesis that there are different levels of organiza-

tion in the neural system. One very basic level of organization reflects neural adaptations in response to evolutionary pressures for the rapid, successful recognition of animate (and plant life) objects. This is the only true categorical organization of conceptual (and perhaps perceptual) knowledge in the brain. In addition, however, it is possible that there is further structure within these broad domains of knowledge. We have proposed that the latter structure is not categorical in form but reflects the correlational properties of members of semantic categories.

METHODS

Subjects

E.W. is a 72-year-old woman who suffered a left cerebral vascular accident in February 1988. CT scans in January of 1995 revealed a large area of encephalomalacia within the left posterior frontal and parietal lobes consistent with the old infarct (from 1988). At the time of the stroke, EW was working in the personnel department of a government agency. She has a high school education and a degree from a secretarial school (i.e., approximately 14 years of schooling). E.W. was first seen by us in February 1996.

E.W. is fluent and produces well-formed, coherent sentences, both in constrained production tasks and spontaneous speech. In response to the "Cookie Theft" picture (Goodglass & Kaplan, 1983), she produced the following: "The boy is on the stool getting the cookie jar. The girl is washing dishes and the water is going all over the floor."

E.W. does not present with any sentence comprehension impairments, and reading of single words is almost perfect. E.W. has significant problems with both written and oral spelling.

It first came to our attention that E.W. had difficulty with animals when she was asked to name pictures included in a screening battery. The only pictures she could not name were pictures of animals. E.W. reported that, "I'm not good with animals. They always give me trouble." Later, we asked E.W. whether she had problems with animals because she never had much experience with them. She responded, "Well, I did know some things about animals. I used to take my kids to the zoo and such. It's worse since I had my stroke. Now, I have no idea about animals at all. They [her speech therapists] used to give me pictures and I told them I couldn't do animals. I can't even think too much about what animals look like."

Five elderly subjects matched in age and education level to E.W. participated in the experiments (mean age: 72.8 years, range: 72 to 73 years; mean education: 12.4 years, range: 12 to 14 years). Not all subjects completed all experiments.

Procedures

Visual Naming Task

The picture set from Snodgrass and Vanderwart (1980) was randomized and presented to E.W. for naming. Each picture was presented on a separate sheet of paper. E.W. was asked to provide the name of each picture, and, if unable to provide the name, to provide any information possible. She was given an unlimited amount of time to respond to each picture.

Five normal control subjects were presented with the complete picture set and asked to provide a name for each picture. This was done to determine if certain pictures elicited alternative, but acceptable, responses that may be particular to the specific age and education level of the patient and to determine if the control subjects would show a familiarity effect in naming. Some pictures were consistently named incorrectly by at least two or more of the control subjects. In these cases, they either provided a superordinate term (e.g., beetle → bug; artichoke → vegetable), could not produce any name (e.g., seahorse → 2 subjects said, "can't think of the name"), provided a semantic description (e.g., caterpillar → thing before it changes into a butterfly; chisel → shaves things), or in one case, could not identify the picture (peach → canteen, fruit, ball, puffy thing). There were a total of 10 items that resulted in misnaming by two or more of the control subjects (ant, bee, fly, beetle, caterpillar, ostrich, seahorse, peach, artichoke, chisel), and these items were removed from all the analyses involving the Snodgrass and Vanderwart picture set.

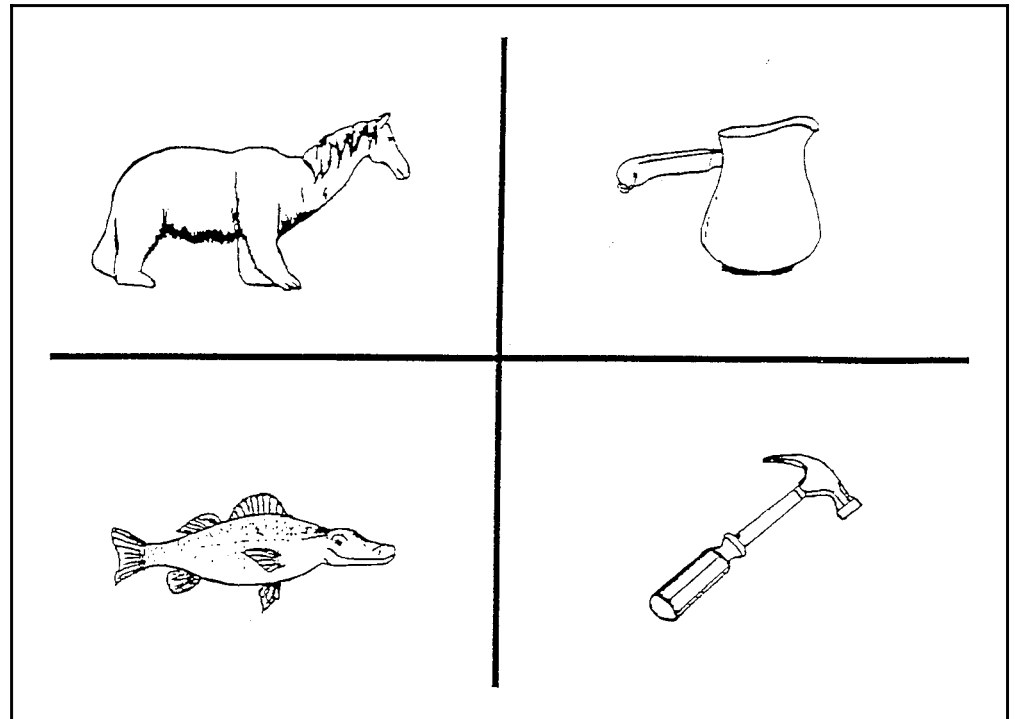
Sound Identification Task

Sixteen animal sounds and 16 nonanimal sounds were downloaded from a digitized sound library (SoundEdit Pro©) onto an audio tape. Presentation order of the sounds was randomized. Three young control subjects listened to each sound, played twice in a row, and were asked to identify the sound. For most items, all three subjects correctly identified a sound. There were several items that elicited alternative but acceptable names, and these were considered correct responses. The sounds were presented to E.W. for identification. She was instructed to listen to the sound and to try and identify it. She was told that some of the sounds were from animals and some were not. This task was administered twice to increase the number of observations.

Object Decision Task

This task was developed to examine E.W.'s ability to distinguish between real and unreal animals and objects using the same number of stimuli in the animal and nonanimal conditions. Also, unreal nonanimal items were developed that were very difficult to distinguish from real nonanimal items to equate more closely the animal

Figure 1. Examples of items used in the Object Decision task. Each item was presented separately.



and nonanimal stimuli on level of difficulty (see examples presented in Figure 1). Thirty animal pictures and 30 nonanimal pictures from the Snodgrass and Vanderwart set were spliced with one another to create unreal animals and objects. The object parts were chosen from items that were similar visually (and had similar parts) but did not belong together.

Part Decision Task

The real and unreal animals and objects used in the Object Decision Task were edited and used in this task. Each “body” was separated from its real and unreal “head” and arranged on a sheet of paper, with the “body” on the top half of the sheet and the two “heads” on the bottom half of the sheet of paper (head and body are in quotes because these terms do not apply directly to the objects—however, we will refer to the parts as head and body for ease of reference). Each head was correctly paired with its body on one trial and incorrectly paired with another body on the second trial (e.g., on one trial a dog body was paired with a donkey head and a dog head; on another trial a donkey body was paired with a donkey head and a dog head). Examples of animate and inanimate items are presented in Figure 2. Items were blocked such that a head pair only appeared once in each block.

Visual Processing Tests: BORB Tests 7, 8, 11, and 12

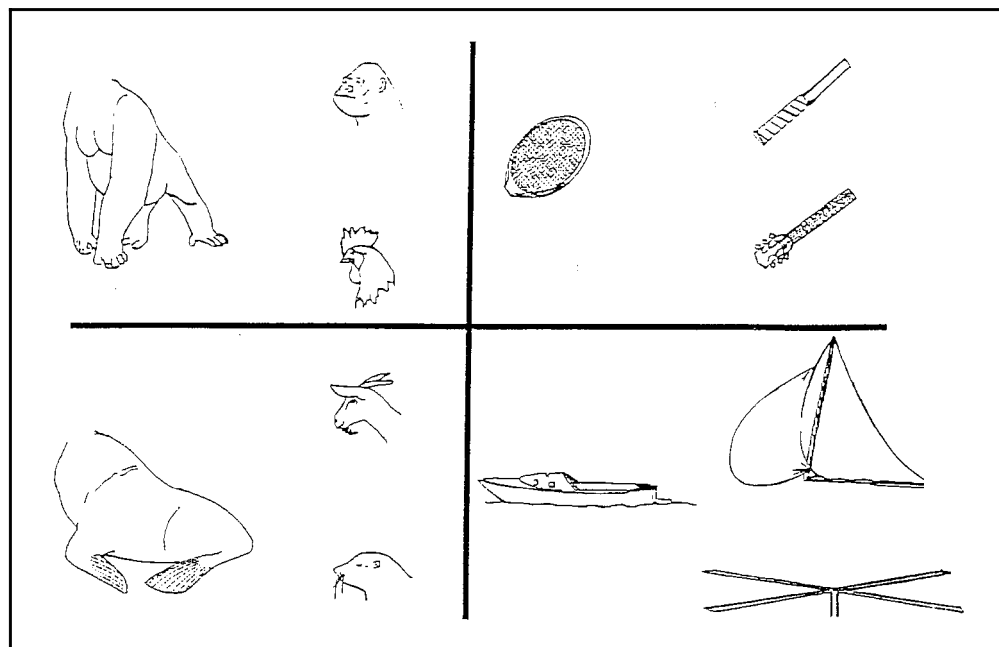
Several tests from the BORB (Riddoch & Humphreys, 1993) were administered to E.W. to assess her ability to

perform complex visual analysis. The tests were administered in the standardized manner. In all tasks, E.W. was presented with a target picture at the top of the page and two probe pictures at the bottom of the page. For each task, E.W. was required to pick the appropriate probe picture, depending on the instructions given. Control data are taken from that reported in the BORB.

In the Minimal Feature View Task (Test 7), the target presents an object pictured in a standard viewpoint. The probe pictures represent either the same object from a different viewpoint or a different object that is visually similar to the target picture and presented from the same viewpoint as the matching probe picture. For example, the target picture of a bus displays a bus when viewed from the side, and the two probe pictures display a bus when viewed from the top and a tractor when viewed from the top. Thus, the main identifying feature of the target object is typically hidden from view, but the shape of the object is relatively maintained. The mean for control subjects was 23.3 ($SD = 2.0$, range: 18.5–25).

In the Foreshortened View Task (Test 8), the target picture presents an object pictured in a standard viewpoint and the probe pictures represent either the same object from a different viewpoint or a different object that is visually similar to the target picture and presented from the same viewpoint as the matching probe picture. For example, the target picture of a car is pictured when viewed from the side and the two probe pictures display a car when viewed from the front and a bus when viewed from the front. Thus, the main identifying feature of the target object is typically in view, but the shape of

Figure 2. Examples of items used in the Part Decision task. Each item was presented separately.



the object is relatively obscured. The mean for control subjects was 21.6 ($SD = 2.8$, range: 16.7–25).

In the Item Match Task (Test 11), the target presents an object from some semantic category, and the probe pictures represent the same object or a different object from the same category. For example, the target picture of a tiger's head is presented with the probe pictures of a tiger viewed from the side and a polar bear viewed from the side. Although Riddoch and Humphreys (1993) claim that this task cannot be done on the basis of visual features, this claim is easily questionable (e.g., one could rely on the stripes of the tiger to match the tiger pictures). We view this task as another measure of visual processing and visual feature matching rather than a measure of access to stored knowledge.

In the Associative Match Task (Test 12), the target presents an object that is associated with one of the two probe pictures. For example, the target of a car is presented with the probe pictures of a road and railroad tracks. The mean for control subjects was 27.5 ($SD = 2.4$, range: 21–30). There are five animal pictures on this test and E.W.'s two errors were on two animal trials. For the picture of the milk bottle, E.W. picked the sheep rather than the cow and for the picture of the egg, E.W. picked the owl rather than the chicken. These are clearly semantic association errors that appear to result from her deficit comprehending information about animals.

Development and Analysis of New Attribute Question Tasks

A number of attribute question tasks were developed to address specific questions regarding E.W.'s category-specific knowledge deficit. For each of these, five elderly

control subjects completed each task in two ways. Subjects were first told to decide whether or not the statement about an object was true (e.g., bears like honey; bears are bred for wool; gloves have a space for each finger; gloves are worn on the head). After making their decision, subjects were asked to rate how confident they were that they knew the answer to the statement on a scale of 1 to 5, with 1 representing "just guessing" and 5 representing "extreme confidence." This was done to examine familiarity of the *question* being asked about an item. Items were matched as closely as possible on familiarity of the concept itself, as determined from the Snodgrass and Vanderwart (1980) norms and/or the typicality ranking from the Battig and Montague (1969) category norms. Items that were unclear to the control subjects and/or were judged to be correct even though they were created to be incorrect (e.g., elephants are brown) were removed from the stimulus set.

Both the control subjects and E.W. completed *all* the attribute questions associated with each item in each attribute judgment task. For each experiment task development is described accordingly. Data presented in Tables 6 through 10 represent a subset of the attribute questions. For each task, items in the specific comparison groups were matched one-to-one on difficulty level of the attribute, as determined by the familiarity ratings given by the control subjects. For example, a comparison of the perceptual attributes associated with their respective animal and object concept is relevant to the investigation. Thus, attribute questions in each of these cells are matched perfectly for difficulty level. Data are presented this way to control for the influence of familiarity or difficulty on the level of performance; however, it should be noted that the pattern of performance is

identical for both the matched data set and the whole data set. To keep the number of items in each cell at a reasonable level, we could not match attributes perfectly for every specific comparison. Note, however, that there is little difference in difficulty level between all the cells (e.g., perceptual animate and associative inanimate).

For the first attribute judgment task, we present data broken down by true and false statements. This was done to demonstrate the lack of response bias for E.W.; that is, she performs equally well (or equally poor) on true and false statements. To simplify presentation of the data for the rest of the tasks, performance is collapsed across true and false statements. E.W.'s performance was always examined for any indication of a response bias, but there was little suggestion of this in any of the judgment tasks.

Attribute Property Task 1: Central Attributes. Forty animals and 46 inanimate items (representing fruits, vegetables, clothing, and tools) were selected and between 1 and 15 attributes about each item was determined. Each item and attribute specific to the item were given to 10 undergraduate students, who were asked to judge whether or not an attribute was characteristic or important in defining that concept. From these judgments, three to six attributes that the largest number of subjects agreed to be important in defining the concept were used. Matching trials consisted of each attribute paired correctly with the corresponding object, and nonmatching trials consisted of attributes pseudorandomly assigned to other items. Matching of items resulted in 98 visual questions each for animals and objects and 57 associative questions each for animals and objects.

Attribute Property Task 2: Food/Nonfood Animals. Nine food animals (chicken, cow, crab, lobster, pig, rabbit, salmon, tuna, turkey) and nine nonfood animals were selected (dog, horse, octopus, pigeon, raccoon, robin, shark, turtle, whale) to serve as items in this task (food and nonfood animals were considered as such for her generation). Six visual attributes and six associative/functional attributes were determined for each item based on information collected from normal undergraduates regarding the attributes most associated with specific items (from the task described above). Nonmatching items were created by pseudorandomly assigning attributes to other items. Five control subjects completed this task. Matched items resulted in 41 questions each for food and nonfood animals in both the visual and associative cells, respectively.

Attribute Property Task 3: General/Specific Property Judgments. Sixty-five animals (15 each for birds, insects, sea animals; 20 mammals) and 45 objects (15 each for fruits, vegetables, buildings) were selected and were matched as best as possible on familiarity (not all items had familiarity ratings because they are not all represented in the Snodgrass and Vanderwart set). Items

within each category (e.g., birds, fruit) were the first 15 items listed in the Battig and Montague (1969) category membership norms. The attributes that were common to all members of a category (e.g., all animals or all buildings) and attributes that were common to only some members of a category are summarized in Table 11. Because of the number of trials ($n = 1165$), an equal number of true and false statements were not created. Instead, each attribute was asked of each item in a category. The table shows the attributes that were queried for each item in each of the four categories tested. Matched items for specific attributes resulted in 100 visual/perceptual questions for both animate and inanimate items and 150 associative/functional questions for both animate and inanimate items.

Attribute Property Task 4a: Size Judgments. Thirty animate pairs and 30 inanimate pairs were developed. One member of the pair was judged to be larger than the second member of the pair, although the distinction required a fine discrimination (e.g., goat-raccoon; tomato-pea). Four control subjects completed this task. Matched items resulted in 18 items in the animate and inanimate categories, respectively.

Attributes Property Task 4b: Other Shared Attributes. Seven attributes that are "shared" between animate and inanimate objects were selected (big, small, number of legs, surface texture, short, tall, color) and 12 items that had one of these features were paired with an item not having this feature, resulting in 42 trials in the animate condition and 42 trials in the inanimate object. Matched items resulted in 42 questions in the animal and object categories, respectively.

Attributes Property Task 5: Visible and Not Visible Attributes. Twenty animals were selected and two to four pictures of these animals were developed. Each picture represented a different view of the animal such that only in one of the pictures showed the experimentally relevant visual attributes of the animal represented. For example, one picture of a horse might have all four legs, a tail, and a mane, another picture of a horse might only be a side view of the head. Attribute questions were developed for each animal picture that were either represented in the picture or were not represented in the picture. This resulted in 95 attribute questions that were answerable based on the information in the picture and 65 attribute questions that were not answerable based on the information in the picture. Each animal was tested only once in a session. E.W. was shown a picture of the animal (e.g., horse) and told, "This is a picture of a horse. I'm going to ask you some questions about horses and you can use the information in the picture to answer them." She was then questioned about attributes associated with a horse (e.g., number of legs, tail, mane).

Table 11. Attributes Included in Property Task

Category	General		Specific	
	Visual	Functional	Visual	Functional
Animal	Mouth	Breathe	Feathers	Lay eggs
	Eyes	Digest	Fur	Live in water
			4 legs	Live on land
			Wings	Fly
Fruit	Skin	Need water to grow	Green	Grow in Massachusetts
		Need sun to grow	Round	Buy frozen
			Red	Buy canned
			Oblong	Grow on a vine
Vegetable	End to cut off	Need water to grow	Green	Grow in Massachusetts
		Need sun to grow	Round	Buy frozen
			Brown	Buy canned
			Oblong	Grow under dirt
Building	Large	Protect from weather	Porch	Use for business
	Roof		Steeple	Use for living
			Brick	Use for religion

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Notes

1. A terminological note: As used here, the category of *living* things includes both animals and plants; the category of *animate* objects includes only animals. Warrington and Shallice (1984) use the term *inanimate* synonymously with *nonliving*. We will restrict the use of *inanimate* to all objects outside of the animal world, in other words, to mean roughly “not en-

dowed with animal life.” In discussing the results on category-specific deficits we will initially use the terms *living* and *nonliving* somewhat imprecisely. Thus, if we state that a subject has selective deficit for the living category, we do not necessarily mean to imply that all subcategories of living things are in fact impaired; it might have turned out, for example, that the impairment concerned only animals. Similarly, the claim that a subject is disproportionately impaired with the living category does not imply necessarily that all subcategories of nonliving things are equally *unimpaired*. Unless otherwise indicated, *living* and *nonliving* are merely shorthand for *predominantly living* and *predominantly nonliving* categories.

In the cognitive neuroscience literature, category-specific deficits have typically been discussed in terms of the *living/nonliving* distinction. In this report we will propose that a more accurate characterization of category-specific deficits is in terms of the *animate/inanimate* distinction, which grows out of evolutionary considerations as well as developmental and neuropsychological data.

2. To be sure, there had been intimations of such a possibility in the neurological literature since Nielsen’s (1946) brief report of two cases who showed disproportionate deficits for living and nonliving things, respectively. But these reports were mostly anecdotal in their characterization of the supposedly selective deficits. Other sporadic reports of category-specific deficits involving one or another conceptual category either did not provide the detailed, quantitative analyses necessary to clearly establish the phenomenon (e.g., Hécaen & Ajuriaguerra, 1956; Yamadori & Albert, 1973) or presented not-easily explicable dissociations (e.g., the selective sparing of the names of countries, McKenna & Warrington, 1978). Furthermore, although the selective deficit of body-part names had already

been clearly documented (e.g., Dennis, 1976; Selecki & Herron, 1965; Weinstein, 1964), discussions of this deficit did not specifically focus on the possibility that the semantic system might be organized categorically. Instead, body-part naming deficits were typically discussed in relation to disturbances of the "body image"—autotopagnosia (De Renzi & Scotti, 1970)—and, consequently, may have been seen as a nontypical semantic domain. Thus, it wasn't until Warrington and Shallice's (1984) paper that a compelling empirical basis was provided for the possibility that the semantic system might be organized categorically.

3. Over the past several years there have been a number of reports of category-specific deficits in patients with degenerative brain disease (see, for example, Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997; Silveri, Daniele, Giustolisi, & Gainotti, 1991). However, most of these reports did not carefully control for various nuisance variables such as differences in familiarity and visual complexity across semantic categories (see below). Furthermore, the results are not obtained reliably, and whenever a category-like effect is obtained, it is rather small by comparison to the effects obtained in the cases reviewed here. We will not discuss these reports.

4. There has also been a different sort of reluctance against adopting the proposal that the semantic system might be organized categorically. It has been voiced most clearly by Farah and her collaborators (Farah & McClelland, 1991; Farah et al., 1996) and represents a basic tenet of associationistic accounts of cognition. They have argued that the adoption of the view that semantic knowledge is organized categorically in the brain would represent "a significant departure from everything else we know about brain organization, according to which subsystems are delineated by function or modality but not by semantic content" (Farah et al., 1996, p. 143). Despite the baldness of this assertion, there is hardly any evidence that speaks directly to the issue of how "semantic content" is represented in the brain. And, in fact, the authors do not provide any relevant citations to empirical evidence that would support their contention. We will discuss recent neuroimaging results that might be relevant to this issue later in the paper.

5. This does not imply that retrieval of nonvisual properties for living things would remain unaffected by damage to visual properties. On the contrary, damage to any definitionally important subset of the semantic properties of objects will affect retrieval of other semantic properties. Thus, damage to the visual semantic subsystem is also expected to affect retrieval of the functional properties of living things but to a lesser extent. See text below for more detailed discussion.

6. There are many other studies of category-specific deficit than are considered in this section of our paper. However, because these studies did not explicitly mention the categories under consideration here, we are unable to unambiguously determine whether the relevant association/dissociation was obtained. For example, Basso et al. (1988), Farah et al. (1989, 1991), Pietrini et al. (1988), Sartori and Job (1988) do not report performance for foods.

7. We consider later Farah and McClelland's (1991) effort to empirically support the (somewhat different) claim that the members of the categories of living and nonliving things depend differentially on visual and functional attributes for their meanings.

8. In the literature on category-specific deficits, the notion of "functional" property is used synonymously with "nonsensory" property. For example, the typical habitat of an animal would be part of the functional properties of that animal.

9. Although the Sartori and Job (1988) are often cited as showing an association of category- and modality-specific *semantic* deficits, this attribution may be inaccurate. The investigation of subject Michelangelo by Sartori and Job focused

principally on his ability to process pictured objects. And, in fact, the authors argue that Michelangelo's deficit may have been restricted to the processing of "structural descriptions" for recognizing objects and not the semantic system itself. Nevertheless, Michelangelo was not consistently better able to process visual as opposed to functional aspects of the *meaning* of living things. For example, he was 100% correct in judging which of two animals was the larger one.

10. There are additional difficulties with this study that make its interpretation highly problematic. To test whether the subject, L.A., had greater difficulty processing the visual or the functional attributes of living category items, the authors used a naming-to-definition task. The definitions stressed either the visual or the functional properties of an animal. However, the animals used in the visual-emphasis definitions were harder to name than those used in the function-emphasis definitions, as indicated by L.A.'s performance in an independent naming task (Exp. C). Thus, the alleged disproportionate difficulty with visual as opposed to functional attributes of living things (Exp. D) cannot be meaningfully interpreted. Gainotti and Silveri (1996) acknowledge this problem and report the results of new experiments that are supposed to be free of interpretation difficulties. These new results are discussed in the main text.

11. It should be noted that this pattern of performance—difficulty in processing only visual attributes of animals—is not compatible with the Farah and McClelland (1991) version of the SFT. This version of the theory predicts disproportionate difficulty for visual versus functional attributes but does not predict complete sparing of functional judgments in the face of severe naming difficulty for living things.

12. The point here is that K.R.'s performance is not explicable by assuming damage to the semantic system, because a consequence of such damage would presumably be the production of nonsystematic errors. The systematicity of the errors might suggest some type of "psychiatric" disturbance. None of this means that the case is less interesting. It does, however, raise the question of whether it is relevant to the issues under consideration here.

13. And even if one were to ignore these problems, there is the additional difficulty that the SFT does not predict just poorer performance in processing visual attributes for the living things category but also for the nonliving things category. This prediction clearly follows from the hypothesis that the underlying cause of the category-specific deficit is damage to a visual semantic subsystem that is presumably shared by all concepts. Consequently damage to this subsystem should also disproportionately impair performance for visual attributes of nonliving concepts (though not to the same degree). However, this interaction has not been systematically observed (e.g., Gainotti & Silveri, 1996). Thus, it does not appear that the investigation of differential performance for visual and functional attributes of concepts has produced a coherent pattern of results on which to base the SFT.

14. The two subjects studied in the Laiacona, Barbarotto, & Capitani (1993) paper were trauma cases, raising the possibility that aetiology may play a role in determining whether or not knowledge of visual and functional attributes are differentially impaired in subjects with category-specific deficits. This possibility is excluded by their more recent study (Laiacona et al., 1997) in which they report two new herpes simplex encephalitis cases with clear category-specific deficits for living things but who, like the trauma cases, show equal levels of performance for knowledge of visual and functional attributes.

15. Shallice (personal communication, April 1997) has also observed that J.B.R. was equally impaired in processing visual and functional attributes of living and nonliving things.

16. The notion of *modality-specific* deficit is multiply ambiguous. One sense of modality-specific refers to a selective deficit

of the *modality of input or output*; that is, the modality of presentation of the stimulus or the modality used for production of a response. In this sense, a modality-specific deficit might refer to a subject who, for example, is disproportionately impaired in processing auditorially presented stimuli. Another sense of *modality-specific* refers to the *type of stimulus* or response. In this sense, pictures and written words are different modalities—visual and verbal, respectively—even though both are presented visually. The third sense of *modality-specific* refers to a *type of knowledge*. In this latter sense, modality refers to the type of properties of objects. Thus, for example, a distinction is drawn between the visual and functional (verbal) attributes of objects. Researchers have not always been careful to distinguish among these senses of *modality-specific*. Unless otherwise indicated here, we will use this term to refer to a type of knowledge.

17. The notion of “denseness” discussed here is to be distinguished from the unrelated notion referring to the *amount* of information one has about a concept—we have lots of information about some things and only sparse knowledge about others. The latter notion of denseness is also likely to figure into the probability that a concept will be adversely affected by brain damage. And it may even play a role in the possibility that semantic deficits may be categorical in nature, in the sense that categories for which we only have little knowledge are more likely to be disproportionately affected by brain damage.

18. It is important to note that the emphasis being placed here on domain-specific knowledge systems as the result of evolutionary adaptations is not necessarily at odds with the OUCH and SFT hypotheses of category-specific deficits. It may turn out that the two types of theories provide explanations of the same phenomenon at different levels of analysis. We explore this possibility in the “Discussion” section.

19. Note that the claim is not that the only types of category-specific deficits that will be observed will involve the categories of animals, plants, and artifacts. Other category-specific types of deficits may be observed, but these will have, by hypothesis, different causes from those for the major categories listed above. We return to this issue in the “Discussion” section.

20. Once again, however, as we shall see in the text below, this account of category-specific deficits does not preclude the possibility of selective deficits restricted to particular modalities of access, such as visual object recognition versus word comprehension.

21. E.W. was administered two other object decision tasks. In both tasks she performed very poorly with animals. On Test 10 of the BORB (Riddoch & Humphreys, 1993), she scored 70% correct for animals versus 94% correct for nonanimals. On another test with 36 items, of which half were real animals and the other half were unreal animals created by combining two halves of different animals, she scored 72% correct.

22. Although the terms *general* and *specific* attributes are related to the concepts of “defining” and “characteristic” feature (Smith, Shoben, & Rips, 1974), we use these terms somewhat more loosely to capture the fact that some properties are much more likely to be shared by members of a category, whereas others may be specific to one or only a few members of a category. Furthermore, the general attributes may not correspond to the technically important features (e.g., egg-laying, biped) of a category but to the perceptually and culturally salient ones.

23. The notions of “shared” or “same” attributes across categories must not be given undue theoretical importance at this point. That is, by using these notions we do not wish to commit ourselves to the view that meanings are built up from a set of semantic primitives that are shared across semantic domains. It may turn out that categories share very few if any attribute

concepts. Thus, for example, the attribute “has wings” (or “has four legs,” “has texture X,” etc.), which may be claimed to be shared across animate and inanimate categories may, in fact, correspond to different attribute concepts in the two semantic domains. That is, perhaps there is no abstract attribute “has wings” that is shared by, say, birds and airplanes; the attribute “has wings” in the domain of animals might be a different concept altogether from the homonymous “has wings” in the domain of vehicles.

24. Farah and McClelland (1991) note that damage to the visual semantic component of their network model also leads to some deficit on *functional* questions. This result, too, is unsurprising given that the meaning of a word depends on the whole set of properties that define it.

25. We thank Martha Farah for making the definitions available to us.

26. We tested 16 subjects. Eight subjects were asked to underline all sensory/perceptual descriptors and the other eight subjects were asked to underline all nonsensory (functional/associative) descriptors for each definition of the set of words used by Farah and McClelland (1991).

27. It is important to emphasize that if Farah and McClelland (1991) had intended all along to restrict the term *functional* to precisely the sense of “having a function,” an equally serious criticism would be raised against the computer simulation. For in this case the dichotomy sensory-functional would fail to capture the bulk of the nonsensory information we have about animals (as argued in the text above). And since functional properties (in the strict sense) do not play a significant role in distinguishing among animals, the computer demonstration would have left out just the important nonsensory information we have about animals.

That the narrow sense of *functional* is not the sense intended by proponents of the SFT is clearly indicated by the fact that in experiments in which they investigate the relative loss of visual and “functional” properties, they have included properties such as carnivore, lives in the desert, etc. (see, for example, Farah et al., 1989). These properties are not functional in the strict sense of “having a function.”

28. That is, those category-specific deficits that are not the result of uncontrolled factors such as familiarity, frequency, complexity, or other idiosyncratic factors concerning the particular histories of individuals with various categories of knowledge.

29. There are reasons for being skeptical of Damasio et al.’s interpretation of the functional basis for their patients’ category-specific naming deficits. They argue that the functional locus of deficit in their patients is at the level of lexical selection and not at the semantic level. They support this claim by noting that they included for analysis only those naming failures for which it could be ascertained that the patient had “correctly recognized” the to-be-named item. The criterion for recognition was that the patient either named the item correctly or provided an adequate description. Thus, they reasoned, if a patient shows disproportionate naming difficulty for a particular semantic category, it could be concluded that this difficulty must arise at a level of processing beyond the semantic level since the to-be-named items were presumably correctly recognized. The authors identify this postsemantic stage of processing as the level at which lexical selection occurs. There are several problems with this conclusion.

The authors do not report evidence that would allow inferences about the integrity of semantic processing in their patients. Thus, for example, no data are reported on comprehension performance; the only data reported are those concerning naming performance. This is unfortunate because to our knowledge all the cases of semantic category-specific deficit in the literature have been reported to have had a deficit

in semantic processing. This is certainly the case for patients with herpes simplex encephalitis, who have all been shown to have had both naming and comprehension category-specific deficits. And, presumably, this would also have been true for the five cases of herpes simplex encephalitis included in the sample of patients tested by Damasio et al. (1996) (who probably were disproportionately impaired in naming animals). In other words, it seems that the criteria used by the authors for establishing that the relevant feature of their patients' naming performance is a deficit restricted to mechanisms of lexical access (as opposed to semantic representations) may have been inadequate.

The latter problem is recognized by the authors, but they go on to argue: "Our scoring procedure ensures that the defects reported here pertain to word retrieval rather than to recognition impairments, even in subjects who showed defects in both naming and recognition" (Damasio et al., 1996; p. 500). This argument is based on the reasoning that the lexical retrieval failure observed in the patients is *in addition* to whatever other difficulty they may have had in recognizing specific to-be-named items. But this reasoning is suspect. Without other information, we do not know whether it is only those patients who showed disproportionate recognition/comprehension failure for the items in a specific category who also showed disproportionate naming failures in that category. Were this the case, we would have grounds for supposing that the locus of functional deficit in these patients probably concerned the semantic level. The mere fact that a patient provides a description of an item that cannot be named does not imply that the basis for the naming failure does not reside at the semantic level of processing. That is, there is little indication that the descriptions provided by the patients were unambiguous. Taken out of context, the "appropriate" descriptions actually may not clearly describe the to-be-named item.

There are other problems of interpretation with the results of this study. Damasio et al. (1996) report that they included for analysis only those patients who "were able to recognize at least 50% of items in each category" (p. 500). Again, without further information it is difficult to interpret the authors' results because the naming data for different subjects could be based on radically different subsets of test items, depending on which items they failed to recognize.

Another problem concerns the method used to determine that a patient had a category-specific deficit. A patient was classified as having a category-specific deficit if naming performance was more than two standard deviations below the mean for the normal controls. This means that it is possible that a patient who scored 1.95 SD below the mean for one category, but 2.05 SD below the mean for another category would have been classified as having a category-specific deficit for the latter category. Unfortunately, unlike other reports of category-specific deficits, the authors do not provide a direct comparison of performance between categories for each patient with putative category-specific deficits. Furthermore, when the problems introduced by this criterion are considered in the context of the scoring procedure used by the authors (the exclusion of an unequal number of trials from different categories for different subjects due to recognition failure), it becomes extremely difficult to compare the putative cases of category-specific deficit reported by Damasio et al. (1996) with other cases in the literature. And, certainly, we cannot be confident that their patients represent cases of category-specific *lexical* as opposed to *semantic* processing deficit.

30. This speculation may provide a basis for the functional imaging results that show extrastriate activation for the category of animals. However, on the negative side, it must be noted that, to our knowledge, there are no cases of category-specific agnosias for the categories of animate and inanimate categories.

Such deficits ought to be observed if there were categorical specialization early in the object recognition system. Perhaps a possible case demonstrating this is the patient reported by Sartori and Job (1988).

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