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Questioning the Living/Nonliving Dichotomy: Evidence From a Patient With an Unusual Semantic Dissociation

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In this article the authors describe a patient (J.P.) whose category-specific naming deficit eluded the classical dichotomies between living versus nonliving items or visual versus functional attributes. At age 22, he had herpes simplex encephalitis followed by a left temporal lobectomy. J.P. was tested on measures of visual perception, category naming, fluency, and name–picture matching. He showed a severe impairment naming and identifying fruits, vegetables, and musical instruments. His performance with animals and birds was spared inconsistently, meaning that even the preserved categories were, at some point, affected. J.P.'s unusual deficit supports the hypothesis that semantic knowledge is organized in the brain on the basis of object properties, which can cut across the living–nonliving categorical distinction.

Evidence from patients with focal brain lesions indicates the presence of category-specific impairments in naming and identifying entities belonging to selective semantic categories. The first detailed investigation (Warrington & Shallice, 1984) described four patients at various stages of recovery from herpes simplex encephalitis (HSE). All were impaired on tests requiring naming or semantic knowledge of living items (e.g., flowers, fruits, trees, vegetables, and animals) but not nonliving items (e.g., clothing, furniture, kitchen utensils, and vehicles). This observation has been replicated in several studies (Basso, Capitani, & Laiacona, 1988; Farah, Hammond, Metha, & Ratcliff, 1989; Sartori & Job, 1988; Sheridan & Humphreys, 1993), providing evidence of a characteristic pattern of dissociation between living and nonliving items. Although it is more common to find natural items impaired and artifactual objects preserved, some patients show the reverse pattern, suggesting a double dissociation (Hillis & Caramazza, 1995; Moss & Tyler, 2000; Sacchett & Humphreys, 1992; Warrington & McCarthy, 1987). Nevertheless, the observation of patients who show patterns of deficit that violate categorical distinctions challenged any simple dichotomy, such as living–nonliving or natural kinds versus artifactual items. For example, case J.B.R. (Warrington & Shallice, 1984) was impaired on biological categories (i.e., fruits, vegetables, fish, and flowers) as well as on some nonbiological categories (i.e., metals, clothes, and precious stones). Similarly, both J.B.R. and the patient studied by Silveri and Gainotti (1988) were impaired on the living categories but not on body parts, which are certainly not artifactual.

Evidence of impairments that violate the dichotomy of living versus manufactured objects led some authors (Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984) to propose reductionist accounts for category-specific deficits. All the different variants of this class of accounts

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(called the sensory/functional theory; Caramazza & Shelton, 1998) focus on the differential role that sensory and functional properties play in identifying members of living and nonliving categories, and on the fact that the organization of conceptual knowledge is based on sensory modality (visual, olfactory, tactile, motor) rather than category. According to this view, damage to a particular semantic subsystem results in a selective impairment for items for which processing is highly dependant on that modality. Damage to the visual semantic subsystem, for example, will result in impairment in those categories for which items are primarily distinguished by their visual properties. A prediction of such a view is that some categories are compromised together because they are distinguished primarily by visual properties (e.g., musical instruments are affected with fruits, vegetables, plants, and animals). Impairment in the functional semantic subsystem results in a selective deficit in categories that are distinguished by functional characteristics (e.g., furniture, vehicles, and tools).

In addition to the broad dissociation between natural and manufactured objects, finer dissociations have been uncovered. Patient M.D. (Hart, Berndt, & Caramazza, 1985) had a selective deficit in naming items in the categories of fruits and vegetables, whereas he was unimpaired in processing items belonging to other natural categories (animals). In contrast, patient E.W. (Caramazza & Shelton, 1998) was severely impaired in visual and auditory recognition as well as in naming and answering questions about members of this category, whereas his performance with other living categories (fruits and vegetables) and nonliving objects was normal. Evidence that the category of animals can be affected independently from the categories of fruits, vegetables, and plants conflicts with the sensory/functional theory because one of the theory's assumptions is that certain semantic categories (e.g., fruits, vegetables, and animals) are impaired together because of their common dependency on a semantic subsystem.

The fractionation of deficits present in the literature has led some researchers to reject the idea of a modality organization of the semantic system in favor of a domain-specific theory in which the semantic system is categorically organized according to evolutionary salient principles. This view permits a limited number of dissociations (e.g., animals and plants vs. artifacts) and rejects the possibility of finer-grained dissociations (e.g., fruits, kitchen items) (Caramazza, Hillis, Rapp, & Romani, 1990; Hillis, Rapp, & Caramazza, 1995; Rapp & Caramazza, 1993); it is consistent with results showing that category-specific deficits are not necessarily modality specific. In fact, not all patients who have deficits in living items show a disproportionate impairment in the visual attributes of objects, which would be expected from selective damage to the visual semantic subsystem (Laiacona, Barbarotto, & Capitani, 1993; Sheridan & Humphreys, 1993).

Another account has been proposed by Tyler and Moss (2001) on the basis of a connectionist model of conceptual structure. They propose a unitary, distributed system in which concepts are defined in terms of properties with different degrees of intercorrelation. The specific prediction of this model is that severity of brain damage is a major determinant of category specificity: Mild disorders should be associated with living impairments, whereas nonliving impairments should be observed only with diffuse, severe damage. Additional predictions include the presence of graded effects and interaction with task demands with more severe impairment on tasks associated with the retrieval of distinctive, rather than shared, features (Tyler & Moss, 2001).

To provide support for the theoretical positions mentioned above, investigators have conducted several functional neuroimaging experiments. Although the presence of different activation for living (especially animals) and nonliving (especially tools) concepts has been reported in numerous studies (Cappa, Perani, Schnur, Tettamanti, & Fazio, 1998; Chao, Haxby, & Martin, 1999; Damasio, Grabrowski, Tranel, Hichwa, & Damasio, 1996; Martin, Wiggis, Undergerleider, & Haxby, 1996; Mummery, Patterson, Hodges, & Price, 1998; Perani et al., 1995, 1999), the results are inconsistent. Recent data from a series of functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) experiments (Devlin, Moor, et al., 2002) have been taken to indicate that conceptual knowledge activates a large, common neural network (mostly in the left hemisphere) that extends from the inferior and middle temporal gyri and the anterior temporal pole to the inferior frontal cortex, without a functional segregation for specific semantic categories or domains. In contrast, a meta-analysis conducted on data from seven PET experiments (Devlin, Russell, et al., 2002) suggested that the category effect is reliable but depends on task demands. Specific activation for tools in the left posterior middle temporal gyrus was found only when participants performed semantic-related tasks (e.g., semantic decision and word retrieval). Bilateral activation of the anterior temporal poles for living items was found when participants were engaged in tasks requiring integration of semantic information (e.g., identification and semantic decision). This study illustrates a task-dependent double dissociation between living and man-made items, a finding inconsistent with theories that claim an undifferentiated organization of semantic knowledge (as proposed by Tyler, Moss, Durrant-Peatfield, & Levy, 2000). Such results are also inconsistent with the idea of a neural specialization for different categories as proposed by Caramazza and Shelton (1998) for animals and tools.

In this article, we report a case of a young patient (J.P.) who shows a complex pattern of dissociations in conceptual knowledge that does not fit easily in any of the patterns predicted by the main theories summarized above. We also present neuroanatomical data from a high-resolution MRI scan to describe the anatomical substrate associated with his selective semantic deficit.

Case Report

Participant

In September 1995, J.P., a 22-year-old, right-handed college student, was admitted to the Berkshire Medical Center with increasing confusion and speech difficulty. He had a

2-week history of severe nausea, vomiting, and diarrhea. Two days prior to admission, he had a temperature of 101° and was confused; his speech revealed word finding errors and paraphasias. A computerized tomography (CT) scan showed a left temporal lobe lesion. MRI confirmed this abnormality and also showed a possible right temporal lobe abnormality. At this time, the patient was still confused and disorientated, with increasing language difficulties and poor comprehension. A lumbar puncture revealed a cerebral spinal fluid pressure of 22 cm of water with 19 polymorphonuclear leukocytes, 63 monocytes, glucose 88, protein 42, and no red cells. He was diagnosed with HSE, and treatment with Acyclovir was started. On September 9, 1995, he was transferred to the Massachusetts General Hospital. An MRI scan with contrast revealed an increased T2-weighted signal with a mass effect in the uncus, hippocampus, and parahippocampal gyrus. An electroencephalograph (EEG) showed abnormality in the left temporal lobe region. Despite the treatment with Acyclovir, his condition worsened, and he became increasingly confused and lethargic. A repeat EEG showed left temporal epileptiform lateralizing discharges, consistent with hemorrhagic herpes encephalitis. A new CT scan revealed hemorrhage in the left anterior temporal lobe with uncal and subfalcian herniation. Because of the progression of the herniation, an emergency left temporal lobectomy with resection of the hematoma was performed. After the operation, J.P.'s condition improved gradually. He was discharged from the hospital on October 14, 1995, and was transferred to a rehabilitation center for cognitive rehabilitation. At that time, his deficits were largely confined to the cognitive domain and, according to a clinical report, included "expressive language disturbance, retrograde memory loss for one year before the illness, as well as a memory deficit for recent events."

The first formal neuropsychological evaluation was performed on October 30, 1995. This examination revealed "persisting language impairments and retrograde and anterograde memory deficit in both the visual and verbal domain." On the Boston Naming Test, he named 5 of 60 items correctly. Immediate memory was normal, as indicated by a digit span of 7. On the Wechsler Adult Intelligent Scale—Revised (WAIS–R; Wechsler, 1981), he obtained a Verbal IQ of 86, a Performance IQ of 100, and a Full Scale IQ of 91. On the Wechsler Memory Scale—Revised (WMS–R; Wechsler, 1987), his scores were in the 12th and 42nd percentiles for immediate recall of visual and verbal material, respectively. On 30-min delayed recall, he scored in the 6th percentile for verbal and 5th percentile for visual material. An evaluation 4 months later revealed an improvement in the visual and verbal domains. On the WAIS–R, his Verbal and Performance IQ scores were 94 and 125, respectively, with a Full Scale IQ of 107. On the WMS–R, he showed an improvement in the visual domain only (99th percentile for immediate recall and 93rd percentile for delayed recall), whereas his performance in the verbal domain was still severely impaired (7th percentile for immediate recall and 1st percentile for delayed recall).

We first evaluated J.P. in April 1996. At that time, his general clinical condition was good, except for a complete anosmia and taste impairment. He and his family reported continuing gradual improvement in cognition, although word finding difficulties were still present. For the first time, his family noticed that naming was impaired in a differential way, with greater difficulty in naming items "that you can buy at the supermarket." In June 1997, he was sufficiently improved to return to college. His language difficulties were lessening, and only the naming impairment remained a concern. Because of his memory deficit and his loss of certain didactically acquired knowledge (e.g., the names of chemical elements), he changed his major from chemical engineering to electrical engineering. We saw him again in July 1999. He had graduated from college the previous month with a degree in electrical engineering and was about to start a new job. His spontaneous speech was fluent, well articulated, and without any sign of difficulty. In August 2001, his recent memory had improved significantly, but he still had difficulties in, for example, taking telephone messages and remembering proper names. When asked about his inability to name vegetables and fruits, he answered that he did not care about food because "I can't taste food anymore, and I'm not interested in it."

We tested J.P.'s cognitive abilities in three different testing sessions over a span of 6 years, from April 1996 to August 2001. In the following text, we report his performance during the most recent testing session, which was carried out from July 1999 to August 2001. The complete longitudinal data set is provided in Appendixes A–H. J.P.'s performance was compared with that of 20 healthy volunteers (HVs), male college students between the ages of 18 and 24 years (M = 22.3). All participants were native English speakers and right handed. They completed all tasks, except that only 10 of the 20 performed the real and unreal test and the visual and functional questionnaire; 5 participants completed the two most recent naming tests.

Assessment of Overall Cognitive Abilities

Despite a general cognitive improvement over time (Appendix A), J.P. remained impaired in the general memory, verbal memory, and delayed recall subtests of the WMS–R (Wechsler, 1981). He also performed below normal on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) and Recognition Memory Test (Warrington, 1984).

J.P.'s visual acuity and depth perception were investigated with the following tests: Snellen Acuity Test (Keystone View, Reno, NV), Randot Stereo Acuity Test (Stereo Optical, Chicago, IL), and Vistech Contrast Sensitivity Test (Vistech Consultant, Dayton, OH). He showed normal performance on these tests, and he also completed four tests of color vision without error: City University Color Vision Test (Fletcher, 1980), Ishihara Test for Color Blindness (Ishihara, 1964), Farnsworth Dichotomous Test for Color Blindness (Farnsworth, 1947), and Lanthony Color Test (Lanthony, 1978). His score on the Benton Facial Recognition Test (Levin, Hamsher, & Benton, 1975) was normal compared with that of the HVs (J.P.'s score = 45, HV M = 47.76, SD = 3.57), as were his scores on the Hidden Figures Test (Thurstone, 1944), on which he achieved 25 out of 27 correct for Part I, 7 of 7 for Part II, 6 of 7 for Part III, and 10 of 10 for both Parts IV and V, all within the time limits. A neuro-ophthalmological examination revealed a modest refractive error in the left eye, correctable with pinhole to better than 20/20. Acuity in the right eye was also better than 20/20. The only possible afferent abnormality was detected in the visual field in the right homonymous superior quadrant. According to the report of the neuro-ophthalmologist, this deficit "was subtle . . . and should not be disruptive for any visual tests." A neurological examination performed on the same date was normal.

Category-Specific Impairment

Here we report the results of nine experimental tasks we administered to J.P. (Table 1). The rationale for our investigation was the following: First, we wanted to assess the presence of category-specificity in his impairment by asking him to name items from a broad range of different semantic categories. In addition, we administered identification tasks to exclude the possibility that his deficit was at a general language level (e.g., anomia) and to assess the presence of a semantic disturbance. Second, we wanted to rule out the possibility that category-specific deficits were artifactual, attributable to variations in item familiarity and visual complexity. We also wanted to rule out the possibility that J.P.'s naming deficit was due to other variables, such as a visual–perceptual impairment. Once we had demonstrated that the deficit shown by J.P. had the characteristic of a semantic deficit, we investigated whether he showed any dissociation in the knowledge about perceptual and functional attributes of objects. This issue is relevant for the interpretation of his deficit in light of current theories of the organization of semantic knowledge.[1]

Results

Picture Naming and Category Identification

On the naming task, J.P. was impaired relative to HVs on fruits, vegetables, birds, insects, musical instruments, toys, and kitchen items. His naming ability was normal for the categories of animals, parts of the human body, tools, clothing, vehicles, and furniture (Table 2). On the category identification task, he did not make any errors (100% correct responses), even in the categories where he made naming errors. HVs achieved the same ceiling performance. A post hoc analysis of three impaired categories (fruits, vegetables, and musical instruments) and three preserved categories (animals, furniture, and vehicles) with items matched for familiarity and visual complexity (Appendixes B and C) showed that his naming impairment in the categories of fruits, vegetables, and musical instruments was not artifactual. The ratings of familiarity and visual complexity were obtained from Snodgrass and Vanderwart (1980) norms and ranged from 1 (*low*) to 5 (*high*) (Appendix H). Items were matched across groups so that mean scores for each category matched. Results of two sample t tests showed no significant differences in familiarity, $t(11) = -0.82$, $p = .429$, or visual complexity, $t(11) = -0.22$, $p = .843$, between spared and impaired items. We also tested statistically the differences between the proportion of correct responses for spared and impaired categories over the three different testing sessions. Results from a proportion test (Newcombe, 1998) showed a significant difference between impaired and spared categories when items were matched for familiarity ($z = 8.8$, $p < .001$) and for visual complexity ($z = 9.5$, $p < .001$). Because of the low number of items in each category, we could not perform a logistic regression analysis.

Although the pattern of performance in categories of insects, kitchen items, tools, and toys was inconsistent over time, J.P.'s performance on fruits, vegetables, birds, and musical instruments was consistently impaired over the three testing sessions (Appendix B), suggesting, at least for those categories, the presence of a genuine semantic deficit.

To rule out the possibility that J.P.'s naming deficit for fruits, vegetables and musical instruments was an artifact because of the limited number of stimuli in each category in the previous naming test ($n = 8$), we introduced a more demanding naming test with a more extended set of pictures (Dell'Acqua, Lotto, & Job, 2000). Moreover, we wanted to eliminate the ceiling effect shown by HVs in the previous naming test. As reported in Table 3, J.P. performed below chance in the categories of fruits, vegetables, birds, flowers, and musical instruments. However, his performance was also below the HV range for items belonging to other categories: For vehicles, furniture, tools, clothing, and animals, his performance was worse than his previous performance for the same categories, where he was considered spared. To assess direct differences between categories, we conducted a series of pairwise logistic regression analyses comparing each category against the others. We entered naming accuracy as the dependent variable and name frequency, concept familiarity, typicality, age of acquisition, name agreement, and visual complexity as the independent variables along with category membership (entered last into the analysis). The results showed that, once possible confounding variables have been taken into account, the categories of fruits and vegetables significantly differed from any of the following categories: animals ($W = 5.08$, $p < .05$), tools ($W = 6.98$, $p < .001$), kitchen items ($W = 3.75$, $p < .05$), clothing ($W = 3.75$, $p < .05$), buildings ($W = 4.44$, $p < .05$), vehicles ($W = 5.68$, $p < .05$), and furniture ($W = 3.89$, $p < .05$). No significant differences were found between fruits and vegetables compared with birds, flowers, and musical instruments. Flowers were also significantly different from tools ($W = 4.58$, $p < .05$) and vehicles ($W = 5.03$, $p < .05$). Musical instruments were significantly different from vehicles ($W = 4.16$, $p < .05$). No significant differences between other variables were found.

[1] According to the literature, some patients with an impairment for living items show problems on tasks involving visual features for living and nonliving objects, although this is not always the case. Other patients are equally impaired in visual and functional knowledge for living and nonliving entities (Barbarotto, Capitani, Spinnler, & Trivelli, 1995), whereas others have a selective impairment for visual features but only for living entities (Forde, Francis, Riddoch, Rumiati, & Humphreys, 1997; Hart & Gordon, 1992).

Table 1
Category-Specific Impairment: List of Tasks and Procedures

Task name	Aim of the task	Procedure
Picture naming	Evaluate J.P.'s naming abilities with items belonging to different semantic categories to establish whether he had a category-specific naming impairment.	Participants viewed 104 pictures from Snodgrass and Vanderwart (1980) on a computer screen and were asked to name them. The size of the picture was approximately 2 × 2 in. We selected 8 items from each of 13 categories (animals, birds, insects, fruits, vegetables, musical instruments, kitchen items, vehicles, furniture, toys, tools, clothing, and parts of the human body).
Category identification	Evaluate whether his deficit is at a level of superordinate categories or in the recognition of items belonging to the same category.	Participants viewed 72 Snodgrass and Vanderwart (1980) pictures on a computer screen. The categories included vegetables, fruits, birds, insects, animals, parts of the body, tools, toys, furniture, kitchen items, and vehicles. Each picture appeared with a choice of 4 categories. Participants were asked to indicate the category to which the item belonged.
Picture matching with a larger set of stimuli	Show that the restricted naming deficit for the categories of fruits, vegetables, and musical instruments was not an artifact due to the limited number of stimuli in each category in the previous naming test ($n = 8$). Eliminate the ceiling effect in the HV scores.	Participants viewed 230 black-and-white drawings of objects belonging to 11 different semantic categories: fruits and vegetables ($n = 35$), animals ($n = 22$), tools ($n = 35$), vehicles ($n = 24$), clothing ($n = 25$), musical instruments ($n = 15$), birds ($n = 20$), furniture ($n = 15$), buildings ($n = 16$), kitchen items ($n = 11$), and flowers ($n = 12$).
Color naming and color object identification	Evaluate his ability to name colors. Evaluate his knowledge about object color, which is considered a particular type of semantic knowledge. Assess differences between categories.	Participants viewed 28 black-and-white pictures on a computer screen, one at a time. The pictures belonged to different categories: fruits ($n = 9$), vegetables ($n = 9$), animals ($n = 7$), insects ($n = 2$), plus 1 bird (penguin). Participants were asked to name the color in which each object appeared most commonly. The computer recorded errors and response times.
Word–picture matching	Evaluate his ability to recognize in a nonverbal task items belonging to different categories. Rule out the possibility that his deficit was at a lexical–retrieval level.	Stimuli were the same as in the category identification task. Pictures were presented on the screen in groups of four. Before each item appeared, the experimenter named the item aloud. Then four pictures appeared and participants were asked to press a key on the computer keyboard corresponding to the position of the item named by the experimenter. The computer recorded response times. The 72 stimuli were divided into three conditions, with 24 presentations for each condition: same category (target stimulus and distractors belonging to the same semantic category, e.g., fruits), same class (target and distractors belonging to the same class, e.g., living things), and balanced (two living and two nonliving items).
Verbal fluency	Evaluate effortful lexical retrieval for items belonging to different semantic categories.	Participants were asked to name in 1 min as many items as possible from each of 13 categories (animals, birds, insects, fruits, vegetables, musical instruments, kitchen items, vehicles, furniture, toys, tools, clothing, and parts of the human body). Responses were tape-recorded. The order of presentation of the categories was randomized on two different forms. Half of the HVs received Form 1 and half Form 2. J.P. completed both forms in different sessions.
Identification of real and unreal objects	Evaluate visual–perceptual abilities and ability to discriminate between real and unreal objects. Rule out the possibility that J.P.'s naming deficit was due to a general visual perceptual deficit with complex visual stimuli or to a loss of structural knowledge.	Participants viewed 72 pictures from Snodgrass and Vanderwart (1980) on a computer screen. The pictures included 24 from each of the following three categories: objects, fruits and vegetables, and animals. For each category, half of the pictures were real objects and half were unreal objects. Pictures of unreal objects were created by assembling parts of real objects. Participants were asked to say whether the picture was a real or unreal object and whether it was an animal, fruit, vegetable, or artifact. They were not asked to name the object.

Table 1 (*continued*)

Task name	Aim of the task	Procedure
Property verification	Verify whether there was equally impaired processing of perceptual and functional features of objects belonging to living and nonliving categories.	Participants viewed a list of 52 object names on the left side of a page and a list of their definitions, in random order, on the right side. We selected 4 object names from each of 13 categories: animals, birds, insects, fruits, vegetables, musical instruments, kitchen items, vehicles, furniture, toys, tools, clothing, and parts of the human body. In the visual condition, definitions of the words were based on visual characteristics of the objects (e.g., couch was defined as "It is long and soft with four legs and cushions"; cow was defined as "It has horns and an udder"). In the functional condition, definitions were given according to functional characteristics of the objects (e.g., the definition of banana was "It can be peeled, sliced, and eaten with cereal"; the definition of pumpkin was, "One can make a face in it on Halloween"). The participants' task was to match each object with the appropriate definition.
Visual and functional questionnaire	Assess his knowledge about visual and functional features of items belonging to categories in which he showed a naming impairment.	This questionnaire assessed J.P.'s knowledge about visual and functional characteristics of items belonging to the categories in which he was impaired on naming, recognition, and fluency tasks (i.e., fruits and vegetables). The list of 80 questions assessed knowledge about visual and functional characteristics of fruits and vegetables. Participants heard 10 names of fruits and 10 names of vegetables. For each word, four questions were asked: two about visual attributes (e.g., "Is the shape of a pear round or oblong?") and two about functional characteristics (e.g., "Does a pineapple grow in warm or cold countries? Do you need a fork to eat a cherry?").

Note. HV = healthy volunteer.

Previous studies showed that a series of factors, such as name frequency, concept familiarity, typicality, age of acquisition, name agreement, and visual complexity can affect naming accuracy. In particular, concept familiarity and age of acquisition are well-established predictors of naming accuracy and have been shown to affect the performance of patients with semantic dysfunction (Lambon Ralph, Patterson, & Hodges, 1997; Lanthony, 1978). To ensure that J.P.'s performance was not influenced by these stimulus variables, we performed a logistic regression analysis by entering naming accuracy as the dependent variable and domain membership (living vs. nonliving) together with another factor (i.e., name frequency, concept familiarity, typicality, age of acquisition, name agreement, and visual complexity) as the independent variables. The results from this analysis showed that only category membership ($W = 11.19$, $p < .001$) and age of acquisition ($W = 4.56$,

Table 2
Picture Naming Task: Percentage of Correct Responses to 104 Pictures in 13 Categories

Category	HV range ($N = 20$)	J.P.
Living		
Fruits	100	50
Vegetables	100	50
Birds	87.5–100	50
Insects	75–100	62.5
Animals	100	100
Human body parts	87.5–100	100
Nonliving		
Musical instruments	75–100	37.5
Tools	75–100	75
Toys	75–100	50
Kitchen items	87.5–100	75
Clothing	87.5–100	100
Vehicles	100	100
Furniture	87.5–100	100

Note. HV = healthy volunteer.

Table 3
Picture Naming Task: Percentage of Correct Responses to 230 Pictures in 11 Categories

Category	HV ($N = 5$) *M*	*SD*	Range	J.P.
Living				
Fruits and vegetables	86.6	4.8	82.5–94.2	34.3
Birds	82	5.7	75–90	45
Animals	100	0	100	81.2
Flowers	83.3	5.9	75–91.6	8.3
Nonliving				
Musical instruments	97.3	3.6	93.3–100	36.4
Tools	95.2	3.35	91.2–100	80
Kitchen items	100	0	100	91
Clothing	99.2	1.8	96–100	92
Buildings	98.75	2.8	93.7–100	68.8
Vehicles	99.1	1.9	95–100	79.2
Furniture	100	0	100	93.3

Note. HV = healthy volunteer.

$p < .05$) affected naming performance. Naming accuracy was not predicted by frequency, concept familiarity, typicality, name agreement, or visual complexity. The significant effect shown by the living factor was due to the severely defective performance with items belonging to the categories of fruit, vegetables, birds, and flowers, even after frequency, familiarity, typicality, age of acquisition, name agreement, and visual complexity were taken into account. Thus, whereas age of acquisition had an influence on naming accuracy, it cannot by itself account for the domain effect.

Identification of Object Color and Color Naming

J.P. performed below the HV range in identifying the real-life color of black-and-white line drawings of objects (J.P.'s score = 20/29, HV $M = 27.8$, $SD = 0.41$). All his errors were for items in impaired categories: fruits (cherry/orange, lemon/orange), vegetables (carrot/red, pumpkin/purple, pepper/white), and insects (spider/brown, bee/don't know). To rule out the possibility that his poor performance in naming the color of objects was due to a general impairment in color naming, we asked J.P. to name the colors of colored circles. A series of 20 colored circles was presented one at a time on the computer screen. As expected, he performed at the level of the HVs (score 100%), indicating that his deficit extends to accessing semantic information about objects (i.e., knowledge about object color).

Word–Picture Matching Task

J.P. made seven errors, six in the same category condition and one in the balanced condition. Errors were one each in the categories of vegetables, animals, insects, musical instruments, and furniture and two in the category of birds. The HVs performed this task without errors. Overall J.P.'s reaction times ($M = 785.23$ ms, $SD = 177.77$) were faster than HVs ($M = 879.5$, $SD = 58.18$). This result suggests that J.P. was focused on the task and that he invested considerable effort in performing. If we consider single category reaction times, however, he was slower than HVs on birds (HV $M = 944.2$, $SD = 269.5$; J.P. = 1,118.83), musical instruments (HV $M = 851.14$, $SD = 225.4$; J.P. = 948.33), and vegetables (HV $M = 975.33$, $SD = 319.8$; J.P. = 1,049.33).

Verbal Fluency Task

We considered J.P. to be impaired when he performed two standard deviations or more below the HV mean score. Using this definition, we identified impairment in the following categories: fruits, vegetables, insects, musical instruments, and clothing (Table 4). The results from this fluency test, together with the results from previous tasks, show a consistent pattern of impairment.

Identification of Real and Unreal Pictures

Some of the patients with a category-specific deficit for living things reported in the literature showed impaired performance on tasks where they were asked to distinguish between real and unreal stimuli (Sartori & Job, 1988). However, not all cases of category-specific deficits for living things were impaired in object decision tasks (Laiacona, Capitani, & Barbarotto, 1997; Sheridan & Humphreys, 1993). Like these unimpaired cases, J.P. performed at the level of the HVs on all categories tested (91.6%, 95.83%, and 100% correct responses for fruit and vegetables, objects, and animals, respectively). This result confirms that J.P.'s impairment in recognition and naming is not due to a deficit in processing complex visual stimuli, and that an explanation in terms of visual impairment cannot account for his semantic deficit.

Table 4
Verbal Fluency: Number of Items in Each Category

Category	HV (N = 20) M	HV (N = 20) SD	J.P.
Living			
Fruits[a]	16	4.8	4
Vegetables[a]	15.05	3.34	4
Birds	17.1	4.85	9
Insects[a]	13.1	2.95	6
Animals	18.89	4.82	13
Human body parts	28.5	7.45	25
Nonliving			
Musical instruments[a]	19.1	4.47	6
Tools	14.35	5.60	6
Toys	14.1	4.25	5
Kitchen items	23.45	6.82	13
Clothing[a]	21.15	4.92	11
Vehicles	15.05	3.9	9
Furniture	13.7	3.74	8

Note. HV = healthy volunteer.
[a] J.P.'s score was 2 *SD*s below the HV mean.

Property Verification

In matching an object with its functional definition, J.P. performed below the HV group in the categories of fruits (J.P. $M = 50$, HV = 100) and vegetables (J.P. $M = 50$, HV = 100). All the other categories were spared (100%). When matching an object with its visual definition, he was below the HV range only for fruits (J.P. $M = 0$, HV range = 75–100), whereas he performed at ceiling for all other categories (Table 5). Considering the average of the scores of three testing sessions across all categories (Appendixes G and H), we calculated J.P.'s z score based on the distribution of the HV scores (for functional matching, J.P. $M = 47.67$, HV $M = 51.65$; for visual matching, J.P. $M = 41.67$, HV $M = 50.9$). The results showed that J.P. was impaired in functional ($z = 4.26$, $p < .0001$) and visual ($z = 5.49$, $p < .0001$) conditions.

Visual and Functional Questionnaire

Compared with 10 HVs, J.P. scored below their mean in answering questions regarding visual and functional properties of fruits and vegetables. His score on the visual task was 70% for fruits and 75% for vegetables (HV range = 95%–100% for both). On the functional task, he achieved 85% correct for fruits and 65% for vegetables (HV range = 95%–100% for both).

Table 5
Property Verification Task With 13 Semantic Categories: Percentage of Correct Responses

	Functional matching		Visual matching	
Category	HV range (N = 20)	J.P.	HV range (N = 20)	J.P.
Living				
Fruit	100	50	75–100	0
Vegetables	100	50	50–100	75
Birds	75–100	100	100	100
Insects	100	100	100	100
Animals	75–100	100	75–100	100
Human body parts	100	100	100	100
Nonliving				
Musical instruments	100	100	100	100
Kitchen items	100	100	50–100	75
Tools	100	100	50–100	100
Toys	75–100	100	75–100	100
Clothing	100	100	100	100
Vehicles	100	100	100	100
Furniture	75–100	100	100	100

Note. HV = healthy volunteer.

Lesion Analysis

J.P. received an MRI scan on July 9, 1999, in a 3.0 Tesla Signa System Scanner (General Electric, Milwaukee, WI) at the Massachusetts General Hospital Nuclear Magnetic Resonance Center. The anatomical protocol included a series of T2-weighted axial images acquired with a 7-mm-slice thickness and no gap between slices. The anatomical boundaries of the lesion were defined using a series of T1 high-resolution axial images (TR 2500; TE 30), with 18 slices that were acquired with a 7-mm-slice thickness and no gap between slices and were aligned such that slices were parallel to an imaginary line drawn between the anterior and posterior commissures. We also acquired 60 sagittally oriented Signa slices with a 2.8-mm thickness and no gap between slices. Images were analyzed using Cardviews (Radermacher, Galaburda, Kennedy, Fillipek, & Caviness, 1992), a software that reconstructs dynamic orthogonal images into the cardinal viewing planes (coronal, sagittal, axial; Appendix I).

The combined result of the encephalitic process and the surgical resection, performed to control intracranial pressure, was an area of damage largely confined to the temporal lobes (with the exception of an extension into the insula on the left side). The temporal lobe lesion was characterized by severe damage to the anterior parts and was much more extensive on the left side. In particular, the left temporal pole was resected, and the right temporal pole appeared atrophic. The medial temporal region was affected bilaterally. The presence of extensive bilateral temporal lobe involvement is consistent with lesion studies describing the neural substrates of lexical–semantic deficits. For example, semantic dementia, which is characterized by severe semantic impairment, is typically associated with atrophy of the temporal pole bilaterally as well as left amygdala, parahippocampus gyrus, fusiform gyrus, and inferior and middle temporal gyri (Graham & Hodges, 1997; Hodges, Patterson, Oxbury, & Funnell, 1992). Further, many patients with category-specific disorders affecting living items have a diagnosis of HSE and associated bilateral damage to the medial and inferior temporal lobes (Gainotti, 2000).

Discussion

The investigation of patients with category-specific disorders of naming and identification has provided important insights about the organization of the semantic system. In particular, the observation of different patterns of impaired and spared performance with specific categories has resulted in the proposal of several models. Our participation in the discussion stems from an investigation of a college student, J.P., who was diagnosed with HSE in 1995. The following paragraphs relate the findings with J.P. to theories about the organization of semantic knowledge in the brain. We refer both to theories based on data from patients with focal brain lesions or degenerative diseases and to recent theories derived from feature types and feature correlational models.

The most evident characteristic of J.P.'s naming impairment was that he was consistently impaired in the categories of fruits, vegetables, birds, and musical instruments, regardless of the task or the set of stimuli used.[2] His naming performance with insects, tools, kitchen items, toys, and vehicles was inconsistent across tasks and testing sessions, probably because of the limitations in the test materials, including a small number of items in some categories (e.g., toys), and difficulty in matching for important variables, such as familiarity (e.g., insects). His naming performance with animals was spared on most of the tasks (Snodgrass picture naming, functional and visual matching, fluency), but in a more demanding naming task with a larger set of pictures (Dell'Acqua et al., 2000), he performed below the HV range and worse than he performed previously. J.P.'s performance in the category of human body parts and furniture was always spared. Results from a property verification task showed that fruits and vegetables were impaired both in functional and visual modalities, whereas his performance in all the other categories was at the level of HVs.

Although it is clear that J.P. had a consistent impairment for the categories of fruits, vegetables, musical instruments, and birds, he also showed some degree of impairment in other categories, depending on the set of stimuli and task demands. Such a finding challenges an interpretation of his deficit in terms of a pure categorical distinction of the knowledge in separate semantic domains, as suggested by Caramazza and Shelton (1998) in their evolutionary account, unless we assume the contemporary presence of damage to more than one specific semantic system. By this view, J.P.'s pattern of impairment would represent a balance of damage to each of the specific semantic systems. How-

[2] In August 2000, J.P. performed a naming task using colored pictures instead of black-and-white drawings (Bunn et al., 1998). Results from this naming task were consistent with those of the previous tasks. His performance with vegetables, fruits, birds, insects, and musical instruments was below chance (correct responses were, respectively, 22.7%, 30%, 40%, 41.6%, and 33.3%). His performance with tools, vehicles, and furniture was without errors (100%). Percentage of correct responses for animals was 84.2.

ever, as Rogers and Plaut (2002) pointed out, as the number of cases showing a narrow category-specific deficit increases, the risk is a proliferation of the number of evolutionary motivated modules, as suggested by Shelton, Fouch, and Caramazza (1998), to account for a selective sparing of body parts. A more parsimonious explanation for such mixed patterns of impairment focuses on properties (features) of the objects. According to such a view, featural representations are the building blocks of conceptual knowledge; different patterns of category-specific deficits result as a consequence of damage to specific types of features (Caramazza et al., 1990; McRae, de Sa, & Seindenberg, 1997; Tyler et al., 2000). We discuss the importance of these models later.

Our results rule out impaired visual perceptual capacities as an explanation for J.P.'s deficit. The neuro-ophthalmological examination did not show any visual defects that would interfere with performance on visual tests. His performance on tests of visual acuity and depth perception was perfect. In fact, he achieved normal scores on all the tests of complex visual abilities (Hidden Figures Test, Benton Facial Recognition Test), and he had no problem determining whether an object was real or unreal, even when the objects represented items he was unable to name (e.g., fruits or vegetables). This finding is in agreement with results from studies with semantic dementia patients who show the same neuropsychological profile, that is, profound deficit on semantic tasks coupled with unimpaired performance on visuoperceptual and visuospatial tasks (Galton et al., 2001). We conclude that J.P.'s difficulty identifying items presented visually was due to a genuine deficit in knowledge of members of specific semantic categories.

Impairment in the categories of fruits, vegetables, and musical instruments was evident even when items were matched for familiarity and visual complexity, indicating that his deficit in these categories was not due to the effect of confounding variables. Moreover, results from a logistic regression analysis across categories showed that variability in factors like familiarity, visual complexity, name agreement, and typicality did not influence his performance. The only factors affecting naming performance were age of acquisition and domain (living–nonliving) membership. Age of acquisition has been found to affect naming performance also in patients with semantic dementia (Lambon Ralph, Graham, Ellis, & Hodges, 1998), a pathology that leads to an inexorable loss of knowledge about concepts and objects. Age of acquisition, however, cannot alone explain the pattern shown by J.P. In fact, previous studies found that age of acquisition is generally lower for animate items than for objects (Morrison, Chappell, & Ellis, 1997; Nickels & Howard, 1995). Thus, patients are expected to show better performance on animate kinds because they are acquired earlier. The effect of domain membership is the reflection of J.P.'s severely defective performance in the categories of fruits, vegetables, birds, and flowers. For the categories of birds and insects, even HVs made numerous errors. Moreover, birds and insects differ from other categories in familiarity and could not be used in the analysis because of their low familiarity. In other categories, such as vehicles, toys, buildings, tools, and kitchen items, J.P.'s performance was variable over time and across the different task and stimulus sets. Thus, for these categories, the presence of a specific impairment should be considered with caution. How, then, can J.P.'s category-specific disorder be interpreted within the framework of current theories about the organization of semantic knowledge in the brain? We consider in turn the leading classes of interpretations that have been proposed to account for semantic category effects.

Sensory Versus Functional Knowledge

Our data do not support the explanation of J.P.'s deficit as an impairment on items whose processing is based on their visual attributes. According to this sensory/functional theory (Warrington & Shallice, 1984), fruits, vegetables, musical instruments, and animals should be impaired together because their processing depends more on visual than on functional–associative characteristics. J.P., however, did not show consistent difficulty in processing animals. This result is in agreement with other evidence showing that the categories of fruits, vegetables, and animals can be damaged selectively (Caramazza & Shelton, 1998; Hart et al., 1985).

The sensory/functional theory predicts that patients with a greater impairment on living things will be more impaired in processing visual attributes for living as well as for nonliving items because of damage to a visual semantic subsystem. Like other patients described in the literature (Laiacona et al., 1993), J.P. did not show a significantly greater impairment in processing visual attributes of living and nonliving items as compared with functional attributes. On a matching task, his performance with visual and functional definitions was impaired as was his performance in answering questions about visual and functional characteristics of fruits and vegetables. Thus, on the basis of these two results, a dissociation between perceptual and functional attributes cannot provide an adequate explanation of his deficit.

Category-Specific Knowledge

The presence of a dissociation within the category of living items rules out the interpretation of J.P.'s deficit as a categorical distinction between knowledge of living and nonliving things. Like other cases described in the literature (Warrington & McCarthy, 1987), he showed a deficit not only on some living categories, such as fruits, vegetables, and (marginally) birds, but also on musical instruments. Further, he was frequently unimpaired on animals and was consistently unimpaired on parts of the human body, which are considered to belong to the category of living entities. According to Caramazza and Shelton (1998), semantic knowledge is organized categorically in the brain, and this organization reflects an evolutionary pressure that led some neural mechanisms to be specialized for recognition of certain stimuli. According to this domain-specific knowledge hypothesis, a distinction exists between animate (animals) and inanimate entities, such as plants and artifacts, because recognition of these categories of stimuli had an evolutionary value. Whereas the dissociation between animals and plants is fully compatible with the categorical account, inanimate entities such as musical instruments are not related to any evolutionarily relevant distinction and thus do not fit this explanation.

Featural Properties-Based Models

Recent accounts have stressed the importance of featural properties in the structure of semantic knowledge. A precursor of this approach is the featural model called organized unitary content hypothesis (OUCH; Caramazza et al., 1990). According to this hypothesis, certain properties that define objects are strongly intercorrelated and are disproportionally distributed in different categories, whereas living things share a greater quantity of more highly correlated properties than those of nonliving items. This heterogeneous representation of semantic properties in the brain allows for different patterns of category-specific defects, each reflecting the distribution of the damage in semantic space. Thus, the occurrence of category-specific deficits is possible without postulating a categorical organization of semantic knowledge.

A normative study by McRae et al. (1997) in which people were asked to list features for natural items and for artifacts provided support for this hypothesis. Statistical analysis demonstrated that features listed for living items (birds, mammals, fruits, and vegetables) were more highly correlated with one another than those listed for nonliving items (clothing, furniture, kitchen items, tools, vehicles, and weapons); unfortunately, musical instruments were not included among their stimuli. On the basis of the results of McRae et al.'s normative study, Devlin and collaborators (Devlin, Gonnerman, Andersen, & Seidenberg, 1998) proposed an intercorrelational account for category-specific deficits. Performing lesion simulations, they found that high correlations between features are "protective" from the effect of "random damage" to the neural network supporting these representations. Conversely, such random damage may affect distinctive features, which are more informative, less correlated, and particularly prominent in the case of artifacts. According to the model, they proposed that in the case of patients with a degenerative disease, such as Alzheimer's disease (AD), damage in the early stage can be considered "random" and may result in defective naming for nonliving concepts. With progression, the increasing extent of brain abnormality leads to compromise of the highly correlated categories. Empirical support for Devlin's model comes from a longitudinal study with AD patients (Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997), where mild dementia patients were more impaired on artifacts than on living items, whereas patients at a more advanced stage of dementia showed a defect in naming living entities in addition to artifacts. This study, however, included only a small number of patients; other studies with more AD patients reported a significant advantage for artifact naming (Gainotti, Silveri, Daniele, & Giustolisi, 1995; Mazzoni, Moretti, Lucchini, Vista, & Muratorio, 1991).

Other proposals have stressed the differential contribution of correlated and distinctive features across concepts. Like OUCH, the model put forward by Tyler and colleagues (Tyler & Moss, 2001; Tyler et al., 2000) recognizes the importance of shared features—and the correlation between features—and stresses the association between functional and perceptual features. According to the model, living things are characterized by a large number of densely correlated shared features (e.g., have legs, have eyes) and by weakly correlated distinctive features. Conversely, artifacts are characterized by fewer, weakly correlated shared properties, while distinctive properties are strongly correlated (e.g., form with function). Living and nonliving things differ also in terms of associations between perceptual and functional features. For living things, correlated perceptual features are associated with biological functions (e.g., "have eyes" and "seeing"), whereas distinctive features are not (e.g., "have stripes" and "tiger"). For artifacts, instead, the association is between distinctive perceptual features and functional or perceptual features (e.g., "have a sharp edge" and "cutting"). Three predictions stem from this model: First, diffuse, random damage is expected to affect living entities earlier than nonliving entities because their distinctive features are only weakly correlated with other properties; second, distinctive features are more vulnerable than correlated features in the case of deficits for living entities; and third, deficits for artifacts arise only when the semantic impairment is severe because the high correlation between perceptual distinctive features and function would render this semantic field more resistant to damage. This last prediction is supported by data from patients with semantic dementia (Moss & Tyler, 2000) but has not been confirmed by three studies with two separate groups of AD patients (Garrard et al., 2001). Predictions are less clear in the case of focal lesions. Tyler and Moss (2001) have tested the hypothesis that distinctive properties should be more affected than shared ones, independent of their functional or perceptual nature. This result was found for animal stimuli in four out of five patients. It seems that in order to explain this effect, some local effect "over and above the general pattern of robustness/vulnerability" is needed (Tyler & Moss, 2001, p. 250). This account does not hold for patients showing the reverse pattern (e.g., impairment for nonliving items and normal scores for living items in the context of a mild impairment). However, it predicts so-called across-categories effects, whereby fruits and vegetables are particularly vulnerable to damage because they have few weakly correlated distinctive properties. This prediction is in agreement with the pattern shown by J.P. and by other patients who also show disproportionate impairment for fruits and vegetables compared with animals (Bunn, Tyler, & Moss, 1998; Laiacona et al., 1997).

Neural Substrate

As underscored by Gainotti (2000), the models discussed above are associated with a different set of predictions about the underlying neurological substrates. In particular, the sensory–functional account predicts that damage to high-order visual processing areas should be associated with impairment for living entities; featural (intercorrelation) accounts emphasize the importance of extent of brain damage, and the domain-specific hypothesis suggests a link between deficits in evolutionary salient categories and limbic lesions. The availability of high-resolution structural imaging of J.P.'s brain allowed us to consider the possible relation between the locus and extent of lesion and the pattern of cognitive impairment. In J.P., the temporal lobe lesions appeared to be relatively selective, that is, mostly anterior, with a left-sided predominance. Other investigations have reported impaired naming for living items after anterior temporal lobectomy (Tippett, Glosser, & Farah, 1996). In a recent study with 79 patients, Strauss et al. (2000) found that left anterior temporal lobectomy affected naming ability for living things but not nonliving things. In Gainotti's (2000) detailed review, bilateral damage to the anteromesial and inferior temporal lobes was consistently associated with semantic impairments for living entities, whereas a selective lexical disorder for the plant category was found in patients with unilateral damage to the left inferomesial temporo-occipital areas. Tranel and colleagues (Tranel, Damasio, & Damasio, 1997) found defective knowledge about animals after medial occipitotemporal lesions, with a greater deficit in right-sided cases. In a PET investigation using a matching task, Perani et al. (1995) found that recognition of animals was associated with activation of occipitotemporal areas bilaterally. This finding was confirmed in other imaging experiments using naming tasks (Damasio et al., 1996; Martin et al., 1996). On the basis of these reports, defective naming and identification of living items could be expected in the present case. J.P. was impaired in several biological entities, but in the category of animals, his disorder was restricted to birds and insects. The apparent sparing of right hemisphere medial temporo-occipital areas in his brain may be responsible for this unusual pattern. It must be noted, however, that a fine-grained correlation between locus of damage and pattern of semantic impairment may be misleading. An area that may appear structurally preserved on MRI may be functionally disconnected and inactive; even the application of quantitative lesion analysis methods, such as voxel-based morphometry (Gitelman, Ashburner, Friston, Tyler, & Pice, 2001), cannot solve this problem. J.P.'s preserved performance with tools is consistent with lesion and imaging data. Defective knowledge about tools was associated with lateral temporo-parieto-occipital lesions (Tranel et al., 1997) and defective tool naming with lesions in posterolateral inferior temporal cortex and the temporoparietal junction (Damasio et al., 1996). Three PET studies (Damasio et al., 1996; Martin et al., 1996; Perani et al., 1995) reported activation in the left middle temporal gyrus and in the left dorsolateral prefrontal cortex for artifacts.

A large body of evidence indicates that the middle fusiform gyrus plays a crucial role in the perception of human faces (Haxby, Hoffman, & Gobbini, 2000; Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997). This area is spared in J.P., and he had no deficit in the recognition of unfamiliar faces. In contrast, he showed a severe impairment in knowledge about people, both from faces and from proper names (detailed findings will be reported in another article). This deficit is in good agreement with his lesion; the crucial anatomical correlate of disorders of knowledge about people is the right temporopolar area (Tranel et al., 1997), and knowledge of proper names has been proposed to depend on the left temporal pole (Damasio et al., 1996). Further, a recent PET study has provided evidence for the role of the anterior temporal lobe in supporting knowledge about people (Gorno-Tempini et al., 1998).

It is noteworthy that more fine-grained distinctions than the living–nonliving dichotomy have been tested using fMRI. Two recent investigations of ventral temporal cortex (Chao et al., 1999; Ishai, Ungerleider, Martin, Schouten, & Haxby, 1999) indicated that different ventral cortical regions responded preferentially to specific categories. Biological entities (faces and animals) were associated with greater activation in the lateral fusiform gyrus. Activation areas for tools and houses were more medial, whereas the inferior temporal gyrus responded maximally to chairs. These studies, however, showed that responses to a specific object category were not restricted to the region that responded maximally for that category, but that all categories activated, to different degrees, a broad region of the ventral temporal cortex. One may conclude from these studies that the representation of properties of objects within the ventral temporal cortex is organized according to object features clustering together, rather than to semantic categories corresponding to specific and anatomically segregated brain areas. Chao and colleagues (Chao et al., 1999) observed two other differences in activation on the lateral temporal surface: superior temporal sulcus activation for biological entities and middle temporal gyrus activation for tools. The former may be related to motion processing, which is specific for animate entities, whereas the latter may be related to the manipulation activity related to tools (Perani et al., 1995). Thus, in the case of J.P., the lesion may be considered to affect areas that play an important role in supporting knowledge for entities that share common processing features.

Conclusion

The unusual semantic dissociation shown by J.P. is more consistent with the presence of a so-called graded impairment rather than an all-or-none deficit—for example, his deficit seems to affect some categories more severely than others, but the effect of the damage extends beyond semantic category boundaries. In fact, his naming performance, even if consistently more impaired in some specific categories, is not perfect in the "preserved" categories. This pattern is difficult to explain in light of a categorical organization of semantic knowledge; conversely, it is more compatible with models in which conceptual knowledge is organized on the basis of integration between feature types and feature properties because these models, as previously pointed out, predict the presence of cross-category effects. In particular, his disproportionate impairment on fruits and vegetables is due to the specific conceptual structure that items belonging to those categories have, for example, distinctive properties that tend to be weakly correlated with other properties and so are vulnerable to the brain lesion. J.P.'s impairment on musical instruments can be interpreted on the basis of the close relatedness of musical instruments and living things, as proposed by Dixon, Piskopos, and Schweizer (2000, p. 160): Items that share many semantic attributes and visual features are "stored close together" in semantic space.

With respect to the anatomical substrates, the locus of J.P.'s lesion predicts preserved visuoperceptual functions (related to sparing of part of the ventral temporal cortex) and impaired knowledge about people (related to bilateral temporal polar damage). Both of these predictions were confirmed. For the other categories, it is difficult to comment on lesion correlations because too little is known about the neural substrate of the categories impaired in J.P. (fruits, vegetables, birds, and musical instruments).

Until now, theories that have tried to account for category-specific semantic deficits have failed to explain unusual patterns of impairment because they have focused on predetermined categorical distinctions. It is possible that different impairments in semantic knowledge are due to focal lesions affecting representations that share feature types as well as degrees of feature correlation, and that these features result in differential anatomical clustering, probably in the ventral temporal cortex. It is also possible that other factors, such as the individual's level of expertise, may affect anatomical localization.

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Appendix A

J.P.'s Performance on Standardized Cognitive Tests Over Three Testing Sessions Relative to Healthy Volunteers (HVs)

Test	HV (N = 20) *M*	HV (N = 20) *SD*	J.P. 1996	J.P. 1997	J.P. 1999
WMS–R					
General Memory	121.58	11.18	84	92	88
Verbal Memory	107.16	32.86	73	88	76
Visual Memory	128.75	8.56	128	101	133
Attention and Concentration	113.07	7.26	105	88	110
Delayed Recall	117.09	14.23	86	107	83
Boston Naming					
Form I (42 items)	40.45	1.43	20	22	24
Form II (42 items)	39.42	1.86	16	20	20
Warrington Faces	43.57	3.80	37	40	44
Warrington Words	46.46	3.45	34	41	36

Note. WMS–R = Wechsler Memory Scale—Revised.

Appendix B

Picture Naming Task With 24 Pictures Matched for Familiarity: Percentage of Correct Responses

Category	J.P. 1996	J.P. 1997	J.P. 1999
Impaired categories			
Fruits	0	25	25
Vegetables	50	25	25
Musical instruments	50	50	50
Preserved categories			
Animals	75	100	100
Vehicles	100	100	100
Furniture	100	100	100

Appendix C

Picture Naming Task With 24 Pictures Matched for Visual Complexity: Percentage of Correct Responses

Category	J.P. 1996	J.P. 1997	J.P. 1999
Impaired categories			
Fruits	0	25	25
Vegetables	25	0	25
Musical Instruments	50	50	50
Preserved categories			
Animals	100	100	100
Vehicles	100	100	100
Furniture	100	100	100

Appendix D

Picture Naming Task: Percentage of Correct Responses to 104 Pictures in 13 Categories Over Three Testing Sessions

Category	HV range (N = 20)	J.P. 1996	J.P. 1997	J.P. 1999
Living				
Fruits	100	20	50	50
Vegetables	100	25	50	50
Birds	87.5–100	37.5	62.5	50
Insects	75–100	62.5	75	62.5
Animals	100	75	100	100
Human body parts	87.5–100	100	100	100
Nonliving				
Musical instruments	75–100	37.5	50	37.5
Tools	75–100	62.5	75	75
Toys	75–100	75	62.5	50
Kitchen items	87.5–100	75	100	75
Clothing	87.5–100	87.5	87.5	100
Vehicles	100	100	100	100
Furniture	87.5–100	100	100	100

Note. HV = healthy volunteer.

(*Appendixes continue*)

Appendix E

Property Verification Task With Functional Definition: Percentage of Correct Responses

Category	HV range (N = 20)	J.P. 1996	J.P. 1997	J.P. 1999
Living				
Fruit	100	50	50	50
Vegetables	100	100	75	50
Birds	75–100	50	100	100
Insects	100	100	100	100
Animals	75–100	100	100	100
Human body parts	100	100	100	100
Nonliving				
Musical instruments	100	100	100	100
Kitchen items	100	100	100	100
Tools	100	100	100	100
Toys	75–100	100	100	100
Clothing	100	100	100	100
Vehicles	100	100	100	100
Furniture	75–100	100	100	100
M	99.32	92.30	94.23	92.30
SD	1.78	18.77	14.98	18.77

Note. HV = healthy volunteer.

Appendix F

Property Verification Task With Visual Definition: Percentage of Correct Responses

Category	HV range (N = 20)	J.P. 1996	J.P. 1997	J.P. 1999
Living				
Fruit	75–100	0	0	0
Vegetables	50–100	75	0	75
Birds	100	100	75	100
Insects	100	100	75	100
Animals	75–100	100	100	100
Human body parts	100	100	100	100
Nonliving				
Musical instruments	100	50	50	100
Kitchen items	50–100	75	50	75
Tools	50–100	75	100	100
Toys	75–100	100	100	100
Clothing	100	100	100	100
Vehicles	100	100	100	100
Furniture	100	50	100	100
M	95.57	78.84	73.06	88.46
SD	3.23	30.36	37.44	28.16

Note. HV = healthy volunteer.

Appendix G

Subset of Stimuli Matched for Familiarity and Visual Complexity in Each Category

Category	Familiarity	Visual complexity
Fruit	strawberry, lemon, watermelon, cherry	strawberry, lemon, watermelon, pineapple
Vegetable	onion, corn, pumpkin, celery	mushroom, pepper, pumpkin, celery
Animals	dog, gorilla, turtle, camel	dog, gorilla, turtle, camel
Musical instruments	trumpet, violin, guitar, piano	trumpet, violin, guitar, drum
Vehicles	motorcycles, helicopter, airplane, bicycle	truck, helicopter, airplane, bicycle
Furniture	rocking chair, stool, table, desk	rocking chair, dresser, table, desk

Appendix H

Ratings for Familiarity and Visual Complexity

Category	Familiarity	Visual complexity
Fruit	3.22	3.11
Vegetable	3.32	3.00
Animals	3.05	3.60
Musical instruments	3.07	3.64
Vehicles	3.34	3.40
Furniture	3.74	2.82

Appendix I

Anatomical Boundaries of J.P.'s Lesions

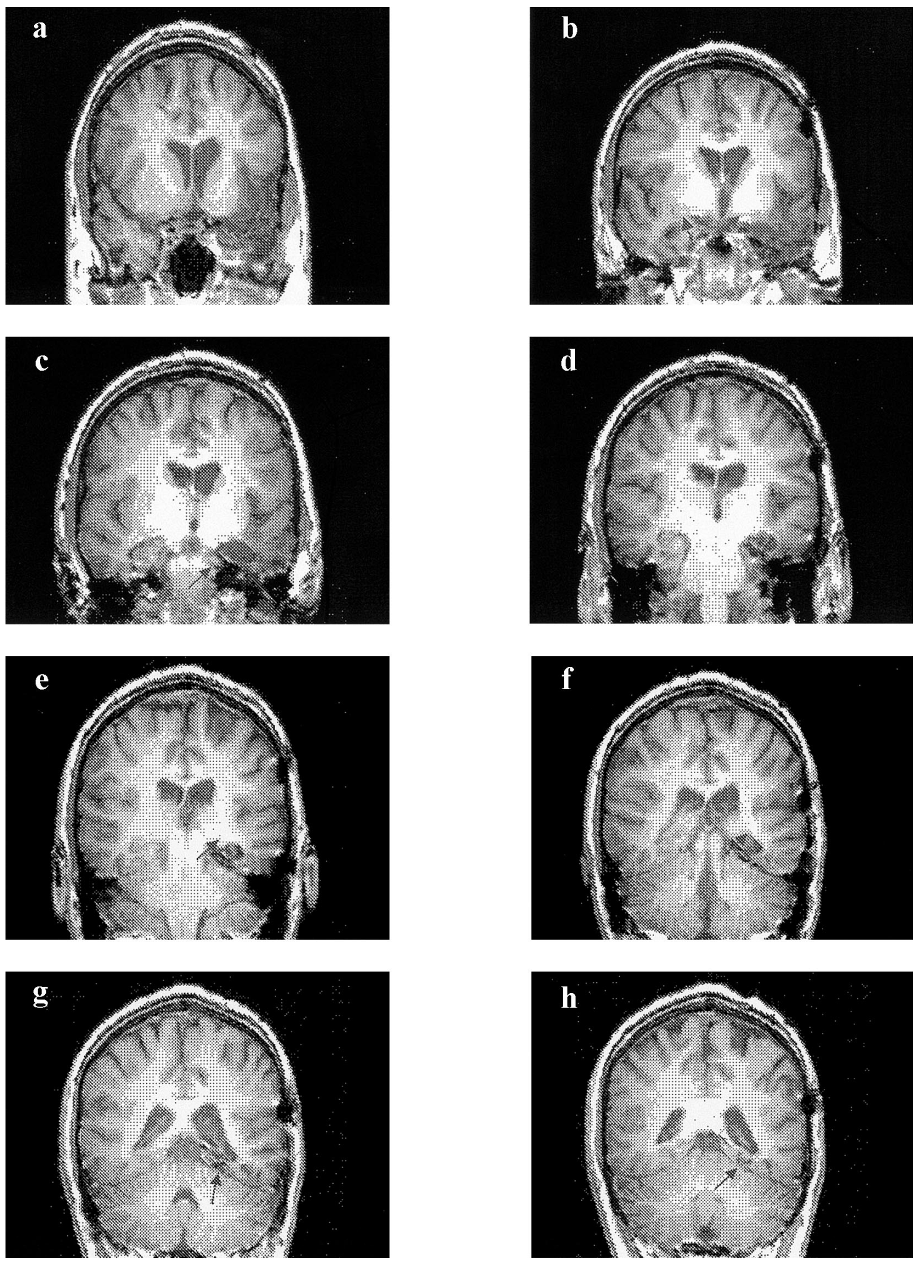

Figure I1. A series of coronal sections (Signa images) arranged from caudal to rostral showing the extent of J.P.'s lesion. In the left hemisphere (right side of image), the lesion invaded the insula, hippocampus, amygdala, and parahippocampal gyrus. The lesion included the entire temporal pole (the area of surgical resection) and extended to the anterior third of the superior temporal gyrus (a, b, c). The middle temporal gyrus appeared to be damaged in its anterior half (a, b, c, d). The posterior third of the inferior temporal and fusiform gyrus appeared to be relatively spared (e, f, g, h). The left lateral ventricle was larger than the right. In the right hemisphere (left side of the image), there was sulcal widening and an enlargement of the temporal horn, indicating shrinkage of the anterior temporal lobe. Signal abnormality was also seen in the anterior fusiform gyrus (b, c, d) and in the white matter just lateral to the temporal horn.

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