

CATEGORY-SPECIFIC NAMING AND COMPREHENSION IMPAIRMENT: A DOUBLE DISSOCIATION

by ARGYE E. HILLIS¹ and ALFONSO CARAMAZZA²

(From the ¹HealthSouth Rehabilitation Center and the ²Department of Cognitive Science, The Johns Hopkins University, Baltimore, MD 21218, USA)

SUMMARY

We describe 2 neurologically impaired patients with lesions involving primarily the left temporal lobe, whose production and comprehension of words in the semantic category of animals were disproportionately *spared* in 1 case and disproportionately *impaired* in the other, in comparison to performance with other common categories. This double dissociation provides neurally based evidence for the view that lexical-semantic information is organized categorically.

INTRODUCTION

Research on language disorders that result from neurological impairment has helped to reveal the cognitive/linguistic mechanisms that underlie language processing. For example, performance by patients who are unable to produce orally the names of objects in response to pictures, despite preserved ability to write their names and preserved motor processes for producing speech, provide evidence for the functional and neural independence of mechanisms for accessing phonological representations of words from those mechanisms used for accessing the orthographic representations of the same words (Caramazza and Hillis, 1990). The detailed investigation of impaired language performance has not only served as the basis for postulating the major component processes that underlie tasks such as naming, but has also played a crucial role in revealing the internal structure of those components. Thus, for example, spared naming and comprehension of nouns in the presence of impaired naming and comprehension of verbs in some patients, and the opposite pattern by other patients, indicate that one of the organizing principles of the lexical system concerns the grammatical class of words (Miceli *et al.*, 1984; *see also* Caramazza and Hillis, 1991; McCarthy and Warrington, 1985; Miceli *et al.*, 1988; Zingeser and Berndt, 1988, 1990). Furthermore, within the class of nouns, patients may have preserved comprehension of abstract nouns along with impaired comprehension of concrete nouns, or the reverse pattern of performance, indicating that concreteness may be another important dimension in semantic processing (Warrington, 1981; Warrington and Shallice, 1984). A still finer organizational structure is indicated by a number of reports showing that naming and comprehension can be impaired in selective semantic categories of concrete nouns, such as animals, fruits and vegetables and so forth (Goodglass *et al.*, 1966; Warrington and McCarthy, 1983, 1987;

Correspondence to: Argye Hillis or Alfonso Caramazza, Cognitive Neuropsychology Laboratory, Department of Cognitive Science, The Johns Hopkins University, Baltimore MD 21218, USA.

Hart *et al.*, 1985; Basso *et al.*, 1988; Goodglass and Budin, 1988; McCarthy and Warrington, 1988; Semenza and Zettin, 1989; for reviews see Berndt, 1988; Shallice, 1988). However, the interpretation of these studies as providing evidence for the hypothesis that the semantic system is organized along the lines of such categories has been challenged, by contending that the observed category differences may reflect no more than differences in the degree of processing demands on the perceptual (or conceptual) system to distinguish between category members (Humphreys and Riddoch, 1987). In this paper, we report 2 patients whose patterns of naming and comprehension, with the same stimuli, were essentially mirror images of one another with respect to performance across categories. Because this double dissociation between categories in naming and comprehension cannot be accounted for by appealing to differences between categories in the degree of processing demands (Shallice, 1988), we argue that the cases provide evidence that it is the organization of semantic information that allows selective preservation or impairment of information in specific semantic categories.

CASE REPORTS

Patient J.J.

Social and medical history. J.J. is a 67-yr-old man who recently retired from an executive position with a large corporation. He completed high school and 2 yrs of college. Four months prior to the initiation of this investigation, J.J. sustained a thromboembolic stroke. A CT scan 2 d post-onset revealed a large area of acute infarction in the left temporal lobe, and 2 focal infarcts in the left basal ganglia region: 1 involving the head of the caudate and another from the anterior limb of the internal capsule extending laterally into the putamen (Fig. 1). He exhibited no dysarthria, ataxia, or limb weakness. Visual field testing 11 mths later indicated very slight decrease on the right.

J.J.'s past medical history is significant for insulin-dependent diabetes, hypertension and atrial fibrillation and is negative for alcohol consumption. He lives at home with his wife and is independent in activities of daily living, although he did not drive until nearly 1 yr after his stroke.

Clinical speech and language evaluation. J.J. was referred to the Medical Rehabilitation Center of Maryland for outpatient language therapy 1 mth after his stroke. His spontaneous speech initially consisted of fluent, English jargon mixed with occasional phonemic paraphasias and neologisms, except for appropriate social expressions. His performance on the Boston Diagnostic Aphasia Examination (BDAE; Goodglass and Kaplan, 1972) indicated profoundly impaired naming and comprehension of printed and

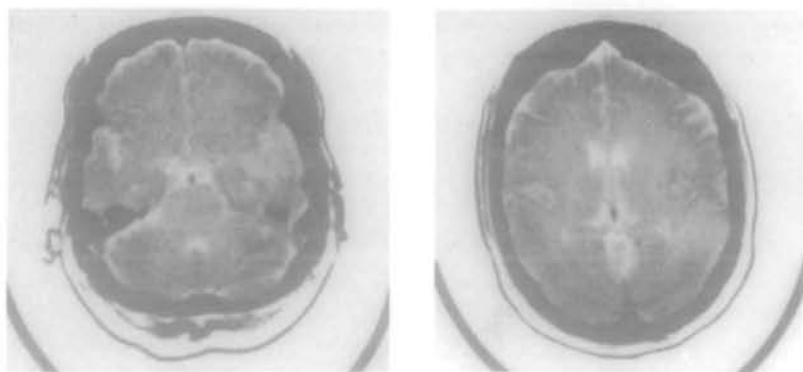


FIG. 1. CT scan of J.J., 2 d post-stroke.

auditory stimuli. Articulation, phonation and prosody were normal. J.J. failed to reach a basal level on the Peabody Picture Vocabulary Test (PPVT). At 16 wks post-stroke, just prior to the experimental testing, he received a PPVT score of 114/175 (standard score of 62; percentile rank of 1) with auditory stimuli and 127/175 with printed stimuli. At the same time, although he had made significant improvement, performance on the BDAE indicated substantial, persisting impairments of comprehension and production of language, reflected in tasks of auditory word/picture matching (59/72 correct); following commands (7/15 points); understanding stories and a contextual questions (7/12 points); repeating phrases (1/16 correct), responsive naming (19/30); understanding printed sentences (6/10); and spelling to dictation (14/25). Spontaneous speech at the time was characterized by fluent, grammatical sentences with frequent circumlocutions and semantic paraphasias and rare phonemic errors. Oral reading was surprisingly good: he made only minor phonemic errors and morphological errors in oral reading of sentences and paragraphs. His score of 37/60 on the Revised Boston Naming Test (Goodglass and Kaplan, 1983) fell within the moderate range of severity. His score of 11/36 on the Modified Token Test (De Renzi and Faglioni, 1978) 6 mths after his stroke was in the 'severe' range of impairment. With printed stimuli, his score improved slightly, to 17/36. His age-corrected score of 33/36 on Raven's Coloured Progressive Matrices (Raven, 1962) was well above the normal mean of 29, consistent with intact visual perception and non-verbal reasoning.

Patient P.S.

Social and medical history. P.S. is a 45-yr-old, right-handed male who completed high-school and is currently president of a small contracting business. P.S. sustained brain injury from a severe blow to his head. CT scans immediately after the accident revealed subdural haematomas in both temporal lobes and a small, focal haematoma deep in the left frontal lobe. A right fronto-temporal epidural haematoma was evacuated by craniotomy. Recent CT scans, taken more than 2 yrs post-injury revealed a large area of damage in the left temporal lobe, and smaller areas in the right temporal and frontal lobes. As can be seen in Fig. 2, the primary locus of impairment, in the left temporal lobe, is more anterior than that of J.J., and has less superior extent.

P.S. did not have any reduction of strength or sensation 1 mth after his accident. Visual fields were full. P.S. was independent in all daily activities, including driving. He resumed working, in a limited capacity due to reading and writing deficits, 1 yr post-trauma. He did not suffer seizures during the time of the investigation.

Clinical speech and language evaluation. Four months after his brain injury, P.S.'s speech was entirely normal except for semantically related word substitutions (e.g. horse/cow) in selective categories. On formal testing, auditory comprehension was also normal, but comprehension was impaired for items that he could not name—animals and vegetables. Like J.J., P.S. exhibited flawless repetition of words and above average performance on the Wechsler Memory Scale visual memory subtest and on Raven's Coloured Progressive Matrices. His primary difficulties were in the areas of reading and writing. His oral reading and spelling were similar to J.J.'s, in that both patients made errors in oral reading and spelling-to-dictation that indicated use of sublexical procedures for converting print-to-sound and sound-to-print (e.g. in reading: *were* →

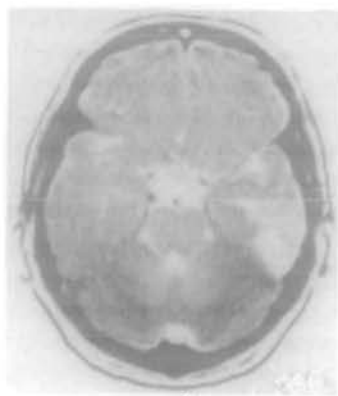


FIG. 2. CT scan of P.S., 2 yrs post-trauma.

'we're'; *says* → /seiz/, rhyming with *pays* by J.J. and *bear* → 'beer' and *mitten* /mɪt ɛn/ by P.S.; in spelling: *SOFA* → *soafa*; *PARROT* → *peret* by J.J.; *OCTOPUS* → *ockdipus*; *TURTLE* → *tertal* by P.S.). P.S. also made frequent visual errors in reading (e.g. *bread* → 'beard'); and his definitions of misread words indicated that he understood the word as his response rather than as the stimulus (e.g. *bread* → 'hair on your face').

EXPERIMENTAL INVESTIGATION

J.J.'s performance on the Boston Naming Test revealed a striking accuracy in naming pictures of animals, relative to other categories of comparable 'difficulty'. This dissociation was particularly conspicuous, because disproportionately *impaired* comprehension and production of words in the semantic category of animals has been reported (Sartori and Job, 1988; Silveri and Gainotti, 1988). It was also noted by P.S. that he had particular difficulty naming animals. Therefore, the following studies were designed to test lexical performance across categories for the 2 patients on the same stimuli.

Materials and procedure

Stimuli consisted of 144 items, from 10 semantic categories, matched for mean word length in letters and syllables. Two groups of 5 categories each were matched for surface and cumulative frequency. Mean surface frequencies for the 2 respective groups were 13.5–16.8 and 43.5–50.4. The list of 144 pictured objects were presented for oral naming once each session across 7 sequential sessions (over a period of 2 wks) to both J.J. and P.S. In order to compare performance across input and output modalities, the entire set of items was presented in separate sessions for oral naming, written naming, auditory word/picture verification, printed word/picture verification, oral reading and spelling-to-dictation. [Performance on reading and spelling-to-dictation will be reported only briefly here; see Hillis and Caramazza (1991a), for further details regarding the data and a possible interpretation.] Stimuli were presented in equal blocks of items for each task, in counterbalanced order, so that each item was presented only once (i.e. in only 1 task) in a single session.

Picture stimuli were black-and-white line drawings, with the exception of a few items that were coloured to distinguish them from related objects (e.g. lemon vs lime). Words were typed on separate cards for oral reading and printed word/picture verification tasks. Written responses that were recognizable as the target (e.g. *LION* → *lyon*) or as a semantically related item were scored as the intended word. For spoken word/picture verification, each word was presented 3 times, in 3 separate sessions, once with the corresponding picture, once with a semantically related picture and once with an unrelated picture. The subject received credit for the item only if his response to the word was correct with all 3 picture foils. The same procedure and scoring was followed for printed word/picture verification.

In the final study reported in this paper, the patients were presented with the name of each stimulus, and were instructed to define it as completely as possible. Responses were recorded and independently scored by 2 examiners, 1 of whom was naive to the purpose and to the hypothesis that had been formulated in the study. Interjudge reliability between scorers was 93.8%, so only the scores of the naive judge are reported.

RESULTS

Category effects

Table 1 shows the substantial advantage for animals over other categories (e.g. furniture, foods, etc.; see Fig. 3) in J.J.'s oral naming performance, and the opposite pattern by P.S., at 4 mths post-injury for each patient. For P.S., performance on the category 'vegetables' is reported separately, because his impairment was as severe for 'vegetables' as it was for 'animals' (whereas for J.J., 'animals' and not 'vegetables' were selectively spared). It is clear from inspection of the results that the opposing dissociations between categories were remarkably stable.

In order to identify the processing component in which the effect arose, performance

on the same stimuli were compared across oral and written naming and spoken and written word/picture verification. These tasks were given at 6 mths post-onset; some were repeated 7 mths later.

J.J.'s oral naming for land animals, water animals and birds ranged from 77 to 100% correct, compared to 8–33% correct for non-animal categories ($\chi^2 = 67.78$; $P < 0.001$; Table 2). Similar differences favouring animals over non-animals were exhibited in written naming ($\chi^2 = 39.49$; $P < 0.001$), spoken word/picture verification ($\chi^2 = 12.29$; $P < 0.001$) and written word/picture verification ($\chi^2 = 61.32$; $P < 0.0001$). There was no difference in accuracy between categories with high frequency items and categories with mid-frequency items for any task (e.g. 30.5% vs 35.5% correct, respectively, for oral naming).

TABLE 1. PERCENT CORRECT ORAL NAMING OVER 7 ADMINISTRATIONS

J.J.	<i>n</i>	1	2	3	4	5	6	7
All animals	46	91	85	72	80	76	74	92
Non-animals	98	12	14	14	11	12	7	17
P.S.								
All animals	46	39	39	39	41	37	48	72
Vegetables	12	25	25	25	25	33	33	42
All other	86	88	91	91	92	94	93	95

TABLE 2. ACCURACY RATES ACROSS CATEGORIES AT 6 MTHS POST-BRAIN DAMAGE

	<i>n</i>	Oral naming	Written naming	Spoken word/picture verification	Printed word/picture verification
J.J.					
All animals	46	91.3	70.0	91.3	97.8
All others	98	20.4	15.3	60.2	42.9
P.S.					
All animals	46	39.1	34.8	93.5	89.1
Vegetables	12	25.0	33.3	91.7	83.3
All others	86	89.5	76.7	100	83.7

On the same set of items, subject P.S. named animals with significantly *lower* accuracy than items in all of the other categories combined, excluding vegetables ($\chi^2 = 29.05$; $P < 0.001$ for oral naming; $\chi^2 = 15.75$; $P < 0.001$ for written naming). P.S. made spoken word comprehension errors only in the animal and vegetable categories. For both patients, error rates were lower in the spoken word comprehension task than in the naming task, presumably because a correct response in word/picture verification does not require complete semantic information. For P.S., written word comprehension was poorer than spoken word comprehension, particularly in categories other than animals and vegetables, because he made visual errors in all categories of words (e.g. accepted *waist* for a picture of a wrist). Hence, category discrepancies in accuracy were masked by these additional errors in otherwise 'spared' categories. However, as discussed further below, P.S. made semantic errors in printed word/picture matching only in animal and vegetable categories. It may also be worth noting that performance on 'fruits' and 'transportation' was better than other non-animal categories for J.J. and worse than

non-animal/vegetable categories for P.S. The possible implications of this observation are taken up in the general discussion.

Retesting 7 mths later, when the patients language performance had improved, showed that the category-specific effect was still present. J.J. correctly named all animals, but only 58–70% of items in all other categories but transportation (Fig. 3). The difference in accuracy between animal and non-animal categories was still highly significant ($\chi^2 = 11.81$; $P < 0.001$). J.J. made no errors in response to any animal names in spoken word/picture verification, but incorrectly accepted 19.3% of the semantically related pictures for the other categories. The opposite pattern of naming impairment in P.S. also persisted ($\chi^2 = 38.71$; $P < 0.001$ for animals vs non-animals, excluding vegetables). He was not retested on the word/picture verification tasks.

Error types

The types of errors made by J.J. and P.S. were similar across the tasks reported here, and were similar for the 2 patients. Table 3 includes examples of errors across tasks, and illustrates that semantic errors occurred in opposite categories for the 2 patients. Error types are described in further detail below, for each task separately.

Picture naming. J.J. correctly named 57% of the 144 pictures. His oral naming errors were most often semantic paraphasias (65% of errors; 28% of responses). The majority of these errors were within-category confusions, such as BOAT \rightarrow 'motorcycle', which

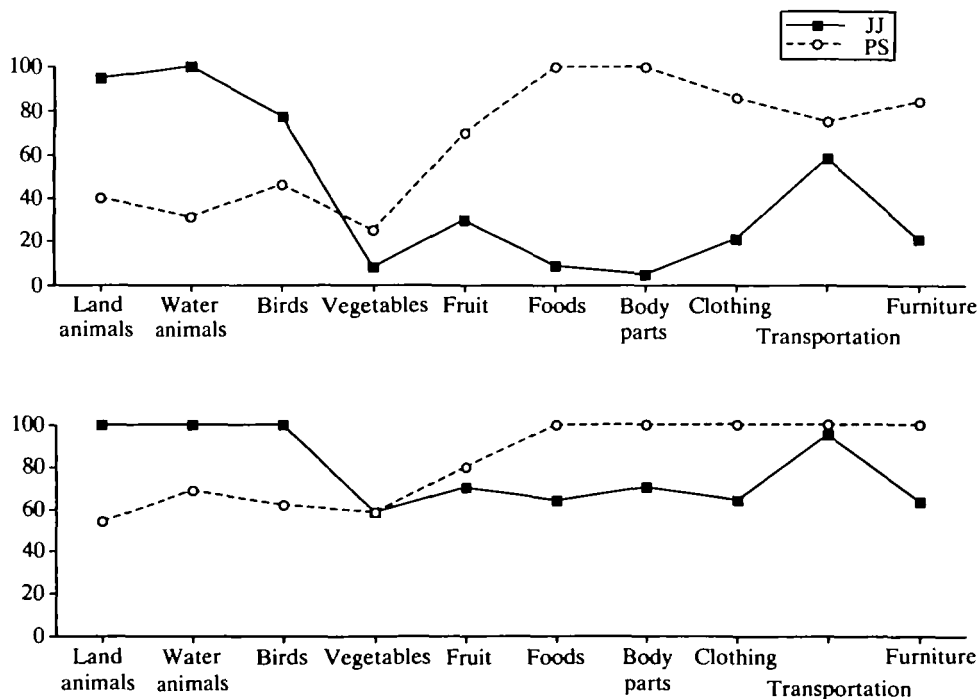


FIG. 3. Percent correct oral naming as a function of category at 6 mths post-onset (*top*) and 13 mths post-onset (*bottom*).

have a 'coordinate' relationship to the target; but a few responses were superordinate labels, such as 'motor vehicle' for TRUCK or other associated words (e.g. BUREAU → 'shoe box'). J.J. also produced some neologisms (4% of responses), circumlocutions (3% of responses), apparently unrelated words (7% of responses) and omissions ('don't know' responses; < 1%). P.S. correctly named 68% of the pictures. All of P.S.'s oral naming errors were coordinate semantic errors (SEAL → 'mouse', 13% of responses) or circumlocutions (e.g. VASE → 'flower holder'; 19% of responses).

Written naming. The majority of each patient's responses in written naming were

TABLE 3. EXAMPLES OF ERROR TYPES ON EACH TASK BY J.J. AND P.S. FOR IMPAIRED AND INTACT CATEGORIES

<i>Stimulus</i>	<i>Oral naming</i>	<i>Written naming</i>	<i>Spoken word/picture verification</i>	<i>Written word/picture verification</i>
<i>J.J.</i>				
Animals				
Shark	+	+	+	+
Crab	+	+	+	+
Donkey	+	+	+	+
Parrot	+	+	+	+
Bear	+	+	+	+
Ostrich	+	+	+	+
Whale	+	+	+	+
Alligator	+	+	+	+
Kangaroo	+	+	+	+
Squirrel	+	+	+	+
Non-animals				
Elbow	Knee	Hand	Wrist	Hand
Bench	Chair	+	Chair	Drawer
Cherry	Grape	Plumb	Grape	+
Sweater	Jacket	Jacket	Coat	Jacket
Apricot	Pear	Pears	+	Berry
Shirt	Silk dressing	Coate	Pants	Sweater
Drawer	Serving device	Vase	+	Chair
<i>P.S.</i>				
Animals				
Dolphin	Flipper	nr	Pelican	Pelican
Kangaroo	Giraffe	nr	+	+
Shark	Whale	Waile	Whale	+
Walrus	Clam	Seal	Seal	Seal
Parrot	S. American	Bird	Penguin	Penguin
	Bird			
Vegetables				
Carrot	Onion	Cyoucumber	Cucumber	+
Bean	Peas	Pea	Pea	Pea
Other				
Drawer	+	+	+	+
Jacket	+	+	+	+
Elbow	+	+	+	+
Bench	+	+	+	+
Helicopter	+	+	+	+
Sweater	+	+	+	+

+ = correct response (with patient's spelling, if not accurate, in parentheses). nr = no response or 'don't know'.

recognizable either as the correct word (e.g. WHALE → *whayle*; LEMON → *lemmun*; 33% of responses by J.J.; MOTORCYCLE → *motor ciekil*; 85% of responses by P.S.) or as a semantic paraphasia (e.g. TOE → *hand*; 58% of responses by J.J.; SHARK → *waile*; 8% of responses by P.S.). The remaining errors were unrecognizable misspellings or 'don't know' responses (8% of responses for J.J.; 6% for P.S.) or unrelated words (e.g. UMBRELLA → *window*; 1% for each). When recognizable spellings are scored as the intended word, the pattern of errors in written naming is similar to the pattern of errors in oral naming of each patient, except that pictures that elicited circumlocutions in oral naming often elicited in written naming semantic paraphasias in J.J.'s case and recognizably correct written names in P.S.'s case. It is quite possible that P.S. would have produced correct oral names for these items following each circumlocution if he had been given additional time (although not formally timed, written naming responses appeared to be more delayed than oral naming responses. Further, P.S. was unlikely to produce circumlocutions—which tend to be lengthy—in writing, because he found writing to be difficult.)

Word/Picture correspondence tasks. Errors in auditory word/picture verification matching tasks by both patients were limited to within-category items. That is, neither patient accepted or selected a semantically unrelated word for any of the picture stimuli. Furthermore, neither patient ever rejected a correct word/picture match. In printed word/picture matching, neither patient accepted words that were phonologically but not visually similar to the name of the picture (e.g. cherry/chair), but P.S. frequently accepted a word that was visually similar to the name of the picture (e.g. bear/bean). These visual errors account for the higher error rates by P.S. in printed word comprehension tasks, especially in categories other than animals and vegetables. In the latter categories, he made primarily semantic errors; for example, he accepted a picture of a dolphin for the word *pelican* and accepted a picture of a walrus as the referent of *seal*. The presence of semantic errors in printed word comprehension, restricted to the categories of animals and vegetables, is consistent with a single impaired mechanism underlying semantic errors in comprehension and naming tasks, in addition to a more peripheral problem that led to visual errors in all categories.

Although it will not be discussed in detail here, P.S.'s difficulty recognizing printed words was also reflected in his oral reading—he made many phonologically plausible errors (e.g. *drawer* → [draʊ]) as well as visual errors (e.g. *beard* → 'bread') in reading words from all categories, in addition to semantic errors (e.g. *deer* → 'bear'; *pea* → 'beet') that occurred primarily in the categories of animals and vegetables. Together with his pattern of performance in the printed word comprehension task, these errors indicated an impairment in accessing the orthographic representation of words in all categories, in addition to the impairment that gave rise to semantic errors on animals and vegetables in all lexical tasks (see Hillis and Caramazza, 1991b, for additional information on P.S.'s reading). His performance in spelling-to-dictation was similar to oral reading in that his most common errors were phonologically plausible misspellings of the stimulus (e.g. 'carrot' → *cairit*, 'kangaroo' → *cangarue*). Thus, the fact that semantic errors were less frequent in oral reading and dictation than in naming tasks, can be accounted for by assuming that P.S. ordinarily accomplished the former tasks—correctly or incorrectly—via sublexical procedures for converting print-to-sound or sound-to-print.

J.J.'s performance in reading and spelling is discussed in detail in a separate paper (Hillis and Caramazza, 1991a). Here we simply note that in oral reading he was 100% correct for animals and 86–100% correct for non-animal categories. Essentially all of his errors were phonologically plausible responses or both semantically and visually related words (e.g. *waist* → 'wrist'). Spelling-to-dictation was very similar to written naming performance at 6 mths post-stroke, but far exceeded naming and comprehension tasks by 13 mths post-stroke. The majority of his errors were phonologically plausible misspellings (e.g. 'mustache' → *mustash*). However, many of his correct responses on the later administration of the task could not be accounted for on the basis of semantic information—which was shown to be impaired for the same items at the same time in word/picture matching tasks—nor on the basis of sublexical information alone (since he correctly read and spelled some irregular words that elicited errors in the comprehension tasks). This pattern of performance may be explained by assuming that J.J. can access lexical-orthographic and lexical-phonological representations on the basis of *combined* input from the semantic system and the sublexical conversion mechanisms—neither of which could alone support accurate selection of the target representation.

Comprehension tasks

In order to more fully assess J.J.'s and P.S.'s word comprehension performance, they were asked to define sets of spoken words. This assessment took place 13 mths after each patient's brain damage; by this time, J.J.'s connected speech had improved sufficiently for him to convey his understanding of stimulus words.

J.J. defined the 144 words that had been used in the earlier tasks. All of his definitions of animals were judged to be accurate by 2 scorers. For example, he defined 'mouse' as 'A small little animal with a pointed nose, pointed ears, and a little snout; about 1 inch high, or 1 ¼ inches. It doesn't have much value, except that it can be eaten by animals. Cats chase them. It eats whatever it can steal in people's houses, even in my house. They move rather quickly, climb up on things, and can stand on two feet.' In contrast to his performance in defining animals words, 15.3% of his definitions of non-animal names were scored as 'clearly wrong' and 8.2% as ambiguous. The definitions scored as errors were either specific descriptions of some object other than the stimulus (such as: *bench* → 'A device you sit on, about 12 inches high with 4 legs. It revolves you around while sitting. Can be made of metal or wood') or acknowledgement of his lack of understanding of the word (such as: *apricot* → 'I don't remember. I've heard of it. It's a fruit, but I don't remember which one. That's strange. I suppose it's sweet.'). Additional examples of his definitions are reported in Table 4.

P.S. defined 70 names of animals and vegetables and 70 names of objects in the other categories previously tested, matched for word frequency. He resolved any ambiguity in his definitions by giving additional information upon request. Responses to 15.7% of animal and vegetable names were wrong. As was the case for J.J., some of P.S.'s error responses indicated that he understood the word as a related item (e.g. he defined 'artichoke' thus: 'Looks like a pear; has a big seed in it'), but most indicated that he accessed minimal, if any, semantic information (e.g. 'leek' was defined as, 'An animal, I've heard of them'). All of P.S.'s responses to words from all other categories were accurate (Table 4).

TABLE 4. DEFINITIONS OF ITEMS IN IMPAIRED AND UNIMPAIRED CATEGORIES

J.J.

Animals

- Lion 'A large animal, about 4 feet tall, maybe taller at the shoulders; it has a long body and very large paws, and stands on all four legs. It has a monstrous head with which it growls; and it has a mane—a large body of hair. It lives in Africa.'
- Heron 'This bird has a long neck and legs. It lives near water. Stands in the water...very tall—maybe about 6 feet. Not brown, but white and blue perhaps.'

Non-animals

- Celery 'Very white-bodied meat...soft...easy to eat.'
- Melon 'I'm not sure. It's a fruit, a soft material. I don't remember if it is yellow or green or orange. I've forgotten too many things.'
- Drawer 'Something that has to be drawn—pictures.'

P.S.

Animals and vegetables

- Heron 'A fish.'
- Salamander 'Sounds familiar... a fish?'
- Aardvark 'Has a duck face that hangs down, a bird that can't fly.'
- Brussel sprouts 'Like rice. You put meat on them.'
- Pinto beans 'I don't know... sounds Mexican.'
- Celery 'Turns yellow if you leave it too long. You steam it and pour melted cheese on it. I don't know if you can eat it raw or not.'

Other

- Apricot 'Like a peach, only smaller. You can buy them canned or dried or fresh.'
- Ottoman 'A chair without a back, that you put your feet on.'

DISCUSSION

J.J.'s ability to name a picture was dependent on the semantic category of the pictured item. He made many more semantic errors in response to items that are not animals than in response to animal stimuli. P.S. showed the opposite pattern: more semantic (and other) errors in response to animals than to non-animal categories. There are 4 important aspects to the reported results: (1) in both patients, the deficit involved both naming and comprehension, and was independent of the form of input—pictures and aurally presented words—and the form of output—written and oral naming; (2) semantic errors were the predominant error type in all of these tasks; (3) the impairment was not uniform across semantic categories, but was restricted to certain categories in each patient; and (4) the semantic categories impaired in the 2 patients were mirror images of each other—a double dissociation.

This double dissociation between categories would seem to indicate that the sort of information that distinguishes members of 1 category from another is an important dimension of the processing structure of at least 1 component of the complex system of naming. Because the impairment involved both comprehension and production, and the errors were predominantly within-category semantic confusions (facts 1 and 2, *above*), the likely locus of damage is to the semantic component of the word processing system. Furthermore, the similar types of errors in oral and written picture naming and word/picture verification (mostly semantic coordinates of the target), and comparable degrees of category effects across tasks suggest that the errors in these 3 tasks have a common source. The only components of the lexical processing system that are common to all picture naming and comprehension tasks are visual/perceptual mechanisms and

the semantic component (*see* Fig. 4). However, the fact that both J.J. and P.S. had category specific impairments in defining auditorily presented words rules out a visual-perceptual basis for the naming and comprehension errors. Therefore, the observed category-specific effects (facts 3 and 4, *above*) are most plausibly assumed to result from damage to the semantic component.

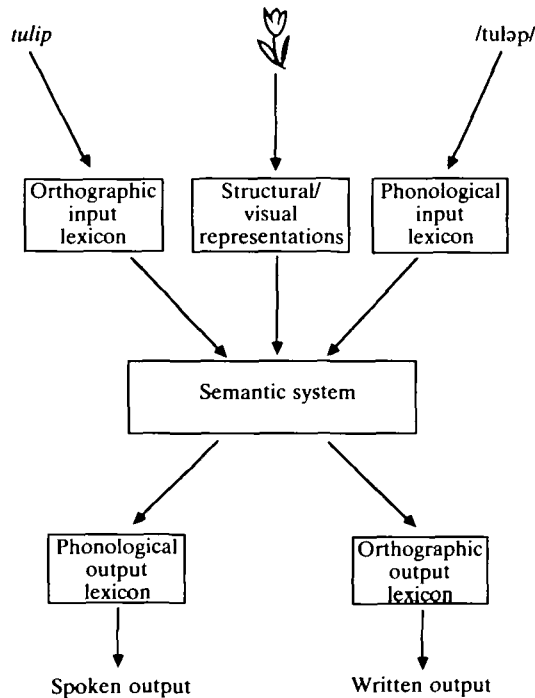


FIG. 4. A model of the cognitive processes that underlie naming and comprehension of words.

The reported results cannot be accounted for by the hypothesis that the observed category differences may be attributable to perceptual characteristics of the categories in question, such as the degree of perceptual (or conceptual) overlap between members of a given category. Humphreys and Riddoch (1987) have argued, for example, that the high degree of perceptual overlap among animals (4 legs, a head and so on), may account for the disproportionately impaired naming and recognition of animals reported for several other patients described in the literature (Sartori and Job, 1988; Silveri and Gainotti, 1988), because of the greater toll placed on the perceptual system to discriminate between members of this category. Consistent with this explanation, the authors reported a patient, J.B., who exhibited greatest difficulty naming items in categories with a high degree of contour overlap and perceptual similarity (Riddoch and Humphreys, 1987). Irrespective of the adequacy of their account for J.B., this proposal cannot explain J.J.'s category effects: his naming was *least* impaired in the categories that presumably require the most difficult perceptual discrimination. Nor can the category effects be explained

as reflections of differences in premorbid familiarity with certain categories. J.J. denied a particular interest in animals; his main avocations were carpentry and mechanics. Interestingly, it was P.S. who reported a special interest in animals: he watched television documentaries about animals, hunted and visited wildlife reservations.

In conclusion, the fact that circumscribed neurological damage can affect some semantic categories and not others supports the hypothesis that information in the semantic component is organized by semantic categories such as 'animals', 'vegetables' and so forth. This leaves open the questions of the proper inventory of semantic categories and of the functional and neural principles that determine category structure. On the latter issue, there are at least 2 alternative accounts that may be offered. In one view, word meanings consist of undifferentiated holistic descriptions with category related items neurally represented contiguously, such that damage to a particular region of the brain will tend to affect members of the same category. An alternative account, that is consistent with other results on semantic processing in other cases (Warrington and McCarthy, 1987; Caramazza and Hillis, 1990; Hillis *et al.*, 1990) is that a semantic representation consists of a set of functional and perceptual features, some of which are common to members of the same category (Miller and Johnson-Laird, 1976; Jackendoff, 1983). On this hypothesis, the semantic representations of related items, say, of DOG <animate, domestic, 4-legged, furry, omnivorous...> and CAT <animate, domestic, 4-legged, furry, carnivorous...>, would consist of overlapping subsets of semantic features, such that damage to some of these features would affect a number of related items. Thus, for example, damage to the features <domestic>, <furry> and <carnivorous> would impede normal processing of the semantic representations of words in the category of animals. Damage to individual semantic features may also account for the fact the damage to 2 or more categories frequently co-occur. For instance, a number of previously reported patients have shown a discrepancy in performance for animate vs inanimate categories (Warrington, 1981; Warrington and Shallice, 1984; Basso *et al.*, 1988; McCarthy and Warrington, 1988), which might be expected if they were differentially impaired in processing one or more features common to the semantic representations of living things. Further, it is interesting to note in this context that patient J.J., who presented with no difficulty in comprehending and producing words in the semantic category of animals, also showed relatively good performance for the transportation category; and that the opposite pattern obtained for the other patient (P.S.). This result invites the speculation that the observed association is not purely accidental but may, instead, reflect the relative sparing or damage of a semantic feature common to the animal and transportation category—perhaps motility.

One possible instantiation of the 'common features' hypothesis has been put forward by Damasio (1990), who proposed that particular neural regions are dedicated to specific sensory 'feature fragments', such as features of an object's physical structure (shape, colour, etc.), operations in space, and value to the perceiver (other aspects of Damasio's proposal, such as representation of combinatorial codes and feedback/feedforward systems are not relevant to the present issue). Damasio contended that neural organization thus reflects features that define entities, but that these features do *not* correspond to boundaries of conceptual categories like 'animals', 'vegetables', etc., but rather, to subgroups within and across categories. Although this conclusion is consistent with many reports of category-influenced performance by brain-damaged patients, the relative specificity of

J.J.'s preservation of the category of 'animals', especially during the latter period of his recovery, indicates that the proposed features represented in specific regions of the brain would necessarily correspond more closely than proposed by Damasio to features that characterize certain conceptual categories.

Independently of whether the 'holistic representation' account or 'featural representation' account, or some other, ultimately proves to be the correct one, the reported double dissociation of category-specific semantic deficits indicates that word meanings are organized in the brain by semantic categories.

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