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Selective Impairment of Semantics in Lexical Processing

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We report the performance of a neurologically impaired patient, KE, whose frequent errors in reading, writing, naming, and comprehension were nearly always semantically related to the target response. To quantify this pattern, a large number of items were presented for tasks of verbal and written naming, oral reading, writing to dictation, word/picture matching, and naming from tactile exploration. Detailed analyses of his performance on these tasks show very similar rates and types of errors, regardless of the modality of stimulus or response. KE's homogeneous pattern of semantic errors across modalities is interpreted as evidence for selective damage to a semantic system common to all lexical processes. In addition, although KE demonstrated some spared knowledge of all items in response to picture stimuli, we were able to interpret all aspects of his performance without resorting to a proposal that there are modality-specific semantic systems. Finally, we show that our interpretation, which assumes a unitary, modality-independent semantic system, can also account for previously reported cases in the cognitive neuropsychology literature that have been taken as evidence for modality-specific semantic systems.

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INTRODUCTION

One type of reading error found in patients with brain damage is the production of a word that is related in meaning to the target response. For example, a neurologically impaired patient may read the word *tiger* as "leopard". Other patients, or even the same patient, may make similar "semantic" errors in other tasks such as picture naming and spelling-to-dictation. Although it would seem uncontroversial that we should be able to take the occurrence of such errors as constituting primae facie evidence for the view that semantic processing mediates input and output mechanisms in reading, spelling, and naming performance[1], it is far from clear what is intended by "semantic processing" or, more specifically, how semantic processing interacts with other processing components in the performance of a particular task. Because of these theoretical uncertainties, experimental results on lexical processing have not led to a consistent and clear hypothesis about the role of the semantic component in the lexical processing system. There is even disagreement about whether the available evidence favours the view that in the cognitive system there is a single amodal semantic system (e.g. Caramazza, Berndt, & Brownell, 1982; Jackendoff, 1987; Riddoch, Humphreys, Coltheart, & Funnell, 1988) versus the view that there are several modality-specific semantic systems (e.g. Paivio, 1978; Shallice, 1987). Elsewhere, we have argued (Caramazza, Hillis, Rapp, & Romani, 1990) that the component semantic systems (e.g. visual semantics, verbal semantics, and so forth) of the multiple semantics hypothesis, as they have been articulated in the neuropsychological literature (e.g. Shallice, 1987), are not sufficiently detailed to represent more than mere labels for reported dissociations of performance. We have also argued that the evidence represented as favouring the proposed distinctions among modality-specific semantic systems does not, in fact, undermine unitary content accounts of semantics. Here, we present a case report of a patient whose performance is explicable by assuming damage to a unitary content semantic system. In this introduction to the case report, we limit ourselves to a brief presentation of the principal components involved in lexical-semantic processing, in the context of a unitary semantics hypothesis. In the discussion section we discuss in some detail the evidence putatively favouring multiple semantics hypotheses.

[1]By this conclusion we do not ignore the fact that oral reading and dictation of certain types of words can occur through nonlexical procedures without semantic processing, but draw attention to the necessary role of the semantic component in normal oral reading (which requires, for example, distinct pronunciations of homographs, like *bow*, in different contexts) and in normal writing (which includes spelling correctly in context homophones, such as bear and bare).

We assume that some levels of lexical and object processing and representation are obligatorily modality specific. The mechanisms that detect those visual features of a tulip which allow it to be distinguished from other visual objects cannot be the same mechanisms as those that detect the phonological features of the spoken word "tulip" in order to distinguish it from other words. Similarly, the phonological mechanisms involved in recognising a spoken word must differ from those visual-orthographic processes that are engaged in the identification of the letter string *t-u-l-i-p* as a familiar word. On this reasoning, we have to assume that there are modality-specific representations that are accessed in the course of recognising words or objects—for written words, an orthographic input lexicon; for spoken words, a phonological input lexicon; and for objects, a system of structural descriptions (for general discussion see Caramazza, 1988; Morton, 1981; Snodgrass, 1984). We also assume that the modality-specific representation that is activated by a particular stimulus (say, the word "tulip") is associated with a modality-independent semantic representation (a set of predicates) consisting of functional, perceptual, and other abstract properties that jointly constitute the meaning of a term (Caramazza et al., 1982). Of course, there are various hypotheses about how the information represented in the semantic system is organised and how it is accessed; but, for the moment, we will ignore these issues. We will consider various possibilities in the discussion section. The crucial assumption is that the meaning of a term is the sum total of various sorts of information including, of course, perceptual, functional, and other abstract properties associated with the word (or object). The proposed organisation of lexical processing may be schematised as in Fig. 1[2]. The aspect of the architecture in Fig. 1 that we wish to emphasise is the central role of a common semantic system in all tasks that involve lexical processing.

A major, if obvious, consequence of the proposed functional architecture of the lexical processing system is that damage to the semantic component will necessarily result in impairment in *all* tasks involving lexical-semantic processing. Furthermore, the nature of the impairment ought to be qualitatively and quantitatively similar across tasks. The latter expectation only follows, of course, on the following assumptions: (1) that there are no additional deficits to other components of processing required for the normal performance of a particular task, and (2) that the types of performance being evaluated across tasks do not differ in terms of the extent to which any one of them may be privileged by some task-specific,

[2]This figure, and Fig. 2, depict only those components that are at issue in the controversy concerning single versus multiple semantics hypotheses; so we have omitted, for example, components of nonlexical systems for assembling reading or spelling responses.

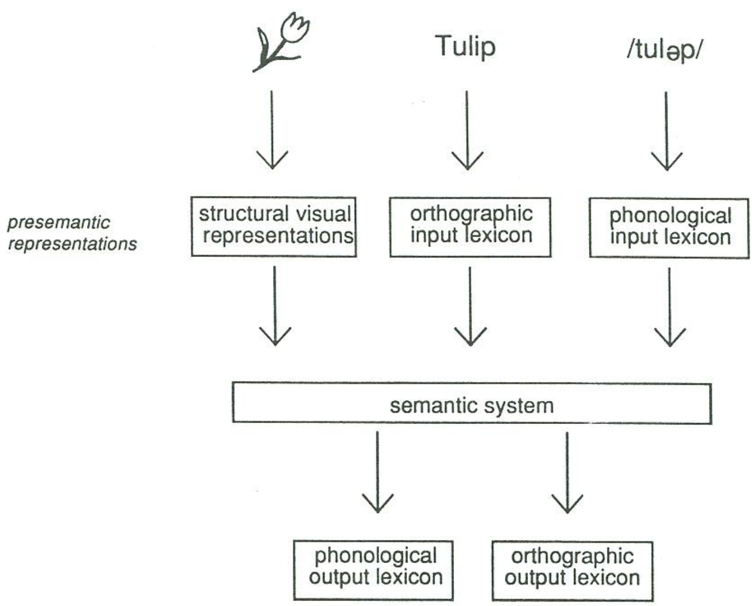

FIG. 1 Modality-independent semantics.

nonsemantic factor. Thus, for example, the first of these two conditions would be violated in the case of a patient with damage to the semantic component *and*, say, damage to the phonological output lexicon. In this case, the patterns of errors across oral naming and written naming tasks would be qualitatively and quantitatively different. The second condition would be violated in those cases where successful performance across tasks depends in part on differential contributions of nonsemantic factors to good performance. Thus, for example, better oral naming performance in response to printed words versus objects might reflect no more than the fact that oral reading may be aided by nonlexical mechanisms for converting orthography to phonology. In this case, differential levels of oral naming performance for objects and words would be uninformative with respect to whether a patient has damage to a unitary semantic system. Similarly, better superordinate categorisation of pictures than of words might occur because categorisation of pictures is facilitated by information about perceptual predicates (say, having a mouth or eyes) that is not directly available from a word. In short, if the two conditions listed here are satisfied, then damage to the semantic system should result in qualitatively and quantitatively similar levels of performance across all tasks involving lexical-semantic processing.

In this paper, we provide evidence for the postulated role of semantics

in lexical processing by considering the performance of a neurologically impaired patient who makes semantic errors in various tasks that require lexical processing. The focus of our analysis is to evaluate the hypothesis that a single lexical-semantic component mediates between input and output orthographic and phonological lexical components. We demonstrate that the patient's pattern of semantic errors is homogeneous across all input and output modalities, and argue that this pattern of performance rules out input or output bases for his semantic errors. His comparable pattern of semantic errors in naming, comprehension, reading and spelling-to-dictation occurred in the presence of severely impaired nonlexical mechanisms for reading and spelling that might otherwise have facilitated his performance differentially for these tasks.

We also report that the patient was capable of producing certain types of appropriate nonverbal responses, such as gestures, to objects that he named incorrectly—a pattern that has been held as evidence that there are separate "verbal" and "nonverbal" semantic systems (see Shallice, 1987, for discussion). However, we argue that the occurrence of appropriate nonlexical responses to objects and pictures that cannot be named need not require us to postulate a separate semantic system for these tasks. In fact, we go on to show that our patient's performance on nonlexical tasks (including adequate gesturing in response to pictures), as well as that of the other cases putatively favouring multiple semantics hypotheses, can be interpreted within a particular modality-independent model of semantic processing—the Organised Unitary Content Hypothesis (Caramazza et al., 1990).

CASE HISTORY

Medical and Social History

KE, a 52-year-old, right-handed male with a M.B.A. degree, was a high-level manager in a large corporation until he suffered a thromboembolic stroke 6 months prior to initiation of this study. A C.T.-scan 5 days post-onset revealed a large area of decreased density in the left fronto-parietal area, compatible with an infarct in the distribution of the left middle cerebral artery. Dense, right hemiplegia resolved over the course of the following 2 weeks to a mild, almost undetectable, paresis of the right upper extremity only. Ambulation improved to a normal gait, but left limb apraxia persisted.

KE received outpatient occupational therapy and speech-language pathology services at the Medical Rehabilitation Centre of Maryland until his sudden death due to cardiac arrest, 11 months after his stroke.

At the time of the study, the patient lived with his wife in their own home. Following his stroke, KE retired from employment, but continued yardwork and played bingo. He drove short distances, to go shopping or banking, prior to his seizures.

Speech, Language, and Cognitive Status

Oral Production. Spontaneous verbalisation predominantly consisted of isolated nouns, including frequent semantic paraphasias and overlearned phrases (e.g. "How are you?", "I'm fine", and "I don't know"). Oral-verbal apraxia was occasionally evidenced in various off-target attempts to produce words or nonverbal, oral movements. However, he was able to repeat single words or nonwords with few misarticulations (single phoneme substitutions, insertions, or transpositions which were frequently self-corrected). There was no evidence of cranial nerve impairment or dysarthria.

Auditory Comprehension. On the Boston Diagnostic Aphasia Examination (B.D.A.E.: Goodglass & Kaplan, 1972) word discrimination subtest, he accurately identified 55/72 (76%) named items, and consistently identified the appropriate category of each. He received a score of 96/175 (standard score of 51) on the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981). On a sentence verification task, responses to active sentences were 72% (86/120) correct, with both syntactic and lexical errors. He responded correctly to 55% (33/60) of passive, reversible sentences and to 63% (38/60) of passive, nonreversible sentences.

Reading. KE was administered portions of the Johns Hopkins University Dyslexia Battery (Goodman & Caramazza, 1986a) to determine the effects of orthographic and lexical parameters on oral reading performance. Since he made no response to the majority of stimuli, statistical analyses of performance were of limited use. Overall, he read correctly only 13/126 (10%) words and 3/68 (4%) pronounceable nonwords. In word reading there was no sign of a frequency effect: an identical number of high-frequency words and low-frequency words was read correctly (5/56; 8%). There was a nonsignificant tendency for nouns to elicit both more correct responses and more semantic errors when compared to words of other grammatical classes. No function words were read correctly. Finally, there was a significant concreteness effect: he read correctly 6/21 (29%) concrete nouns and 0/21 abstract nouns ($\chi^2_1 = 4.86$; $P < 0.03$), which were matched for frequency and word length.

The results made it clear that nonlexical, orthography-to-phonology conversion procedures did not contribute significantly to KE's reading performance. His errors in word reading consisted primarily of failures to

respond at all. Most other errors were word responses that were semantically (and sometimes morphologically) related to the target (e.g. *starve* → "hungry"; *bought* → "buy"[3]). Remaining errors were unrelated words (e.g. *decent* → "angry"), words that were phonologically and/or visually related (e.g. *spend* → "send"), and rare neologisms (*bullet* → "tentle" [tɛntəl]); nonword phonologically plausible renderings of words were not produced. The only nonwords that were read correctly were pseudohomophones that were visually similar to concrete nouns—*mushrume*, *skurt*, and *cherch*. Remaining responses to nonwords consisted of 63 omissions ("don't know" responses), 1 visually similar word error (*hannee* → "hankie"), and 1 error semantically related to a visually similar word (*windoe* → "shutters"). He performed at chance level (50%; 16/32) in matching auditory to printed words in a subtest of the Minnesota Test for Differential Diagnosis of Aphasia (M.T.D.D.A.; Schuell, 1972). Additional evidence for the conclusion that his error responses did not tend to bear a phonological relation to the stimulus is discussed in detail in the Experimental Investigation section.

Writing. On various clinical assessments, such as the M.T.D.D.A. and the B.D.A.E., KE accurately spelled only concrete nouns. On a list of concrete nouns from the Johns Hopkins Dysgraphia Battery (Goodman & Caramazza, 1986a), he correctly spelled 7/17 high-frequency words, 11/17 medium-frequency words, and 10/17 low-frequency words. His errors in dictation were predominantly semantic paragraphias ("money" → *dollar*), unrelated (e.g. "telephone" → *gun*) or mixed (e.g. "screwdriver" → *screwswitch*). His spontaneous writing also included mostly semantic errors (e.g. *Pam, Ken birthday . . . 12/1/56* for *Amy and Ken's 30th wedding anniversary is 12/1*). A screening test of writing to dictation indicated that essentially all of his responses to abstract nouns, verbs, functors, and adjectives were word responses that were unrelated to the stimulus (e.g. "many" → *near*; "listen" → *thrown*. He wrote both unrelated words and nonwords in response to dictated nonwords (e.g. "ribe" → *torn*; "dankle" → *throught*), but none of his responses even vaguely suggested a contribution of nonlexical, phonology-to-orthography translation procedures. Only one response in the error corpus from the combined tests was phonologically plausible ("carrot" → *carrott*). Although the spelling data from these clinical assessments are somewhat meagre, they clearly indicate that KE's writing was not significantly aided by nonlexical spelling procedures.

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[3]Throughout this paper, printed word stimuli and responses are italicised and spoken word stimuli and responses are in quotation marks. Names of picture stimuli are neither italicised nor in quotes. The stimulus precedes the arrow, and the response follows the arrow.

Other Cognitive Skills. KE performed mathematical calculations normally. He did not err in addition, subtraction, multiplication, or division of 2–4 digit numbers. His wife reported that he balanced their checkbooks independently. KE's score of 33/36 on Raven's Coloured Progressive Matrices (Raven, 1962) was significantly above the mean of 29, consistent with intact visual perception and reasoning skills. He completed block design problems without error.

During the course of speech therapy, it was noted that KE made similar semantic errors in word/picture matching tasks, oral naming, writing, and reading. The following study was designed to investigate this observation further.

EXPERIMENTAL INVESTIGATION

We sought to determine if KE's performance on tasks involving semantic processing was homogeneous across input and output modalities—a pattern that would suggest selective damage to lexical-semantic processing components. To distinguish between selective damage to the semantic system versus multiple loci of damage, to either input or output mechanisms (or to multiple semantic systems), we presented KE with the same pool of items in different forms (pictures, objects, words), in different perceptual modalities (visually and tactually presented objects; written and spoken words), and requiring different responses (reading, writing, naming, word-picture matching, drawing and gesturing in response to words). These tasks were selected because they all normally require access to semantic information[4]. Although procedures for mapping orthography to phonology, or vice versa, certainly might normally facilitate oral reading and spelling to dictation, and might alone support reading or writing to dictation of certain words, KE's reading and writing performance provides the basis for dismissing the contribution of nonlexical reading and spelling mechanisms to his performance[5].

[4]This assertion is clear if we consider reading or writing words like *lead* in specific contexts—neither of which is possible without some semantic information. However, many authors (e.g. Bub, Cancelliere, & Kertesz, 1985; McCarthy & Warrington, 1986; Schwartz, Saffran, & Marin, 1980; Shallice, 1988b; Shallice, Warrington, & McCarthy, 1983) have proposed that oral reading can occur via direct, lexical procedures without accessing semantics, on the basis that some patients can read words, including *some* irregular words that they fail to understand. Goodman and Caramazza (1986b) and Kremin (1987) make a similar argument for adequate dictation without semantics. However, we argue in the General Discussion section that these authors have not adequately established complete abolishment of semantics in these patients who are able to read or spell lexically, and that the reported performance patterns might be explained by an interaction of the lexical-semantic system and ortho-phonological conversion mechanisms—neither of which needs to be entirely spared (see Hillis & Caramazza, Note 2 for detailed discussion).

Methods

Stimuli

Over a period of five months, KE was administered two lists of items for various tasks. Most tasks were replicated by retesting. The two administrations of List 1 (a & b) varied in the type of task used for assessing word comprehension.

List 1a. The 144 stimulus items were selected from 10 semantic categories (which are listed in Table 9). All categories were matched according to length in letters (means = 5.1 to 5.9) and in syllables (means = 1.4 to 1.9). Two groups of 5 categories each were matched for word frequency. Mean frequency values for the "high-frequency" group ranged from 43.5 to 50.4. Means for the "medium-frequency" group ranged from 13.5 to 16.8 (norms from Carroll, Davies, & Richman, 1971).

These stimuli were presented for the following tasks: oral picture naming, written picture naming, oral reading, writing to dictation, and comprehension. The word comprehension tasks involved drawing a picture of the referent of the word *or* miming the appropriate use of the object (whichever the examiner judged to be more suitable for conveying recognition of the object). Black-and-white line drawings were used for the naming tasks. Separate cards each bearing one stimulus name in large letters were presented for reading tasks.

Unfortunately, the comprehension tasks used in the presentation of List 1a failed to provide reliable information. The pictures and mimes produced by KE in response to words presented auditorily or in written form were discarded from further analyses, because a high proportion of the responses could not be scored unambiguously as correct or as semantic errors (e.g. drawings of tomato, apple, and cherry were essentially identical), despite the fact that he showed normal mechanics of drawing (see examples in Appendix A) and limb movement. Two examiners scoring responses as correct/ambiguous/wrong respectively judged as ambiguous 34% and 41% of the gestures, and 44% and 43% of the drawings. Moreover, while interjudge reliability (point-to-point percent agreement)

[5]Of course, if we had found, for example, a discrepancy between tasks of comprehension and, say, reading or writing to dictation, we might have been forced to entertain the possible contribution of nonsemantic components of lexical processing. But no such discrepancy was found.

in scoring gestures was quite high (93%), agreement in scoring drawing responses was only 66%. However, it was possible to glean one reliable and interesting result from these comprehension tasks: KE produced a substantial number of gestures that were clearly wrong in response to words. That is, 6/29 (21%) of the gestures for auditory words and 8/30 (27%) gestures for printed words were scored as unambiguously wrong by both judges. For example, he mimed eating with a knife and fork in response to the word *ostrich* and pantomimed riding (as if on a horse) in response to the word *monkey*. In contrast, when he was asked to produce gestures for pictures of the same items, there were no clearly wrong responses identified by either judge, although an equally high percentage (49%, compared to 45% in response to words) were scored as ambiguous.

List 1b. This list consisted of the same 144 items described for List 1a, and was presented 11 weeks after the presentation of List 1a. The reason for administering the new list was two-fold: (1) to use a less troublesome comprehension task, and (2) to re-test the original tasks in order to measure response consistency.

The following four tasks were administered in the same manner as for List 1a: oral picture naming, written picture naming, writing to dictation, and oral reading. In addition, an auditory word/picture matching task and a written word/picture matching task were included to provide alternative assessments of word comprehension. For these tasks, each picture from the original 144 stimuli was presented simultaneously with an auditory or a printed word, and the patient was instructed to confirm or reject correspondence between them. Three trials with each auditory and each printed word were assessed: one with the correct (corresponding) picture, one with a semantic foil, and one with a control foil. Each block of 24 items was presented once with each word and a picture foil or match (selected randomly from the three response choices); then the entire block was repeated with a different foil or match, and so on; so that the same word was not presented three times in a row. An item was scored as correct only if KE responded correctly on each of the three trials that contained it[6].

[6]The design of this task followed from our preliminary hypothesis (from clinical assessment) about the form of KE's impairment in semantic processing. We conjectured that he accessed some, but not complete, semantic information from object names. If so, performance on forced-choice matching tasks would be substantially better than performance on the other lexical tasks. For example, if the word *tiger* activated semantic information about animals or felines, but not sufficient information to distinguish tigers from other animals or from other felines, then he should choose the correct response equally as often as a semantic foil. Of course, in naming, reading, or writing tasks, this inadequate semantic representation might also sometimes activate the correct output representation, as well as output representations of semantic associates. Thus, a forced-choice task would only only be equivalent in task demands to the production tasks if foils included *all* items in his vocabulary that corresponded to the incomplete semantic representation. Because we cannot possibly identify a priori the appropriate set of items, we required instead that KE accept the correct word/picture match *and* reject a closely related item (and reject an unrelated item) presented with the word, to demonstrate comprehension. When he had previously made a semantic error in response to the item in a different task, the picture corresponding to his semantic error was presented as the semantic foil, to increase the likelihood of selecting a foil that would be consistent with his impoverished semantic information. We expected that KE would accept virtually all of the correct word-picture matches *and* accept the semantic foil of items that activated impaired semantic representations, such that the number of items scored as wrong would approximate the number of errors in other lexical tasks if all of the tasks are mediated by the same semantic system.

Thus, chance level of performance on the comprehension task was 0.50 × 0.50 × 0.50, or 0.125 proportion correct. Each semantic foil was a semantic co-ordinate of the stimulus, chosen from the same 144 items: whenever possible (82/144 items), a previous semantic error produced by KE for the stimulus word (when he was tested on List 1a) was used. The control foils were semantically unrelated items chosen from the original picture stimuli. An attempt was made to select pictures with visually similar names as control foils. Forty-eight control foils corresponded to visually similar words (e.g. *beard–bread*; *pear–bear*: most of these were also phonologically similar), and the remainder shared the initial letter and/or word length in letters.

List 2. This list was constructed in order to compare performance with tactile input to performance on tasks with visual or auditory input. Stimuli included 47 items from the categories of fruits, vegetables, clothing, tools, and household items. Items were selected so as to be readily identifiable by tactile exploration. Line drawings were used for picture naming and printed cards for reading. The mean frequency of object names was 21 (range = 0.2–78; S.D. = 19; Carroll et al., 1971).

List 2 was administered twice. The first time, the items were presented in the following tasks: oral naming from tactile presentation, oral naming of pictures, written naming of pictures, oral reading, and writing to dictation. Six weeks later the original tasks were re-tested, along with tasks of *written* naming of objects from tactile presentation, auditory word/visual object verification, and printed word/visual object verification. The two word/object verification tasks were administered in the manner described earlier for word/picture verification. Since the second administration provides a more comprehensive comparison across modalities, results from the first administration were used only for test-retest reliability measures. The results of the first administration were essentially identical to those of the later administration, with the single exception that KE's earlier performance was slightly more influenced by spelling and articulatory difficulties.

Procedure and Scoring

During each session the various tasks were presented in a blocked fashion, in counterbalanced order, such that the patient was never presented with the same item more than once in a single session.

Interjudge reliability in on-line scoring of at least 100 responses was 100% for written responses and 97.6% for verbal responses. Given the high degree of reliability of scoring on these tasks, only the scores of the primary examiner are reported. There were no time limits in any of the tasks. The patient was tested 3 to 5 days each week, during a period when he was receiving on-going speech-language therapy. Although his spelling accuracy, articulation, and nonverbal, oral volitional movements improved, his lexical errors in naming remained at a stable level over the course of the study, except on stimuli that were specifically trained in speech therapy (none of which were included in this study).

The focus of our analysis was on semantic errors. We considered a semantic error to be any response bearing a semantic relationship to the target: associative (e.g. pie → apple), superordinate (pie → dessert), co-ordinate (pie → cake), synonymic (pie → tart), etc. The few neologisms and nonresponses were classified separately. Recognisable words with single phonemic/phonetic errors (e.g. *fox* → "fok" [fak]) or single-letter spelling errors (e.g. "pelican" → *pelicar*) were scored as the intended word.

Results

In order to evaluate the hypothesis that KE's errors had a common source, we have organised the presentation and discussion of the results according to the types of analyses performed on the data, as follows: (1) analysis of error types and rates across tasks and modalities, (2) determination of task interdependence, (3) a comparison of intra- and inter-task item consistency, (4) analysis of responses to previously produced erroneous responses, and (5) a comparison of intra- and inter-task consistency across semantic categories.

Analysis 1: Error Types

Error types and rates for List 1a, 1b, and 2 are presented in Tables 1, 2, and 3 respectively. The total number of errors was very similar across modalities within each list, across administrations, and across lists. Overall error rates ranged from 43—46% ($\chi^2_3 = 0.19$; $P = 0.98$; n.s.) for List 1a; 37—47% for List 1b ($\chi^2_5 = 3.15$; $P = 0.68$; n.s.) and 32—47%

TABLE 1
Error Rates Across Tasks for List 1a

Task	*Total Errors* *N*	*Total Errors* %	*Semantic Errors* *N*	*Semantic Errors* %
Oral Naming	66/144	45.8	49/144	34.0
Written Naming	65/144	45.1	41/144	28.5
Oral Reading	62/144	43.1	44/144	30.6
Writing to Dictation	63/144	43.8	30/144	20.8

TABLE 2
Error Rates Across Tasks for List 1b

Task	*Total Errors* *N*	*Total Errors* %	*Semantic Errors* *N*	*Semantic Errors* %
Auditory Comprehension	61/144	42.4	58(+<3[a])/144	40.3–42.4
Reading Comprehension	53/144	36.8	39(+<13[a])/144	27.1–36.1
Oral Naming	64/144	44.4	59/144	41.0
Written Naming	67/144	46.5	50/144	34.7
Oral Reading	60/144	41.7	52/144	36.1
Writing to Dictation	60/144	41.7	40/144	27.8

[a]Rejection of correct matches.

TABLE 3
Error Rates Across Ten Tasks for List 2

Modality *Input*	*Modality* *Output*	*Total Errors* *N*	*Total Errors* %	*Semantic Errors* *N*	*Semantic Errors* %
Visual: Picture	–Oral Name	19/47	(40.4)	18/47	(38.3)
	–Written Name	18/47	(38.3)	16/47	(34.0)
Visual: Word	–Oral Name	20/47	(42.6)	20/47	(42.6)
	–Picture Verification	15/47	(31.9)	15/47)	(31.9)
Auditory: Word	–Written Name	16/47	(34.0)	14/47	(29.8)
	–Picture Verification	19/47	(40.4)	19/47	(40.4)
Tactile: Object	–Oral Name	22/47	(46.8)	21/47	(44.7)
	–Written Name	19/47	(40.4)	16/47	(34.0)

(χ^2_7 = 3.03; P = 0.88; n.s.) for List 2[7]. In all modalities, for all lists, the majority of incorrect responses were semantic errors. There were no significant differences in semantic error rates among tasks on any list: rates of semantic errors (percent of total *responses*) ranged from 21—34% (χ^2_3 = 6.62; P = 0.09; n.s.) for List 1a; from 28—42% (χ^2_5 = 9.53; P = 0.10; n.s.) for List 1b; and from 30—44% (χ^2_7 = 4.01; P = 0.78; n.s.) for List 2.

On the word/picture verification tasks of List 1b, KE accepted the correct picture matched with the auditory word stimulus for 141/144 items, and the correct picture with the printed word stimulus for 131/144 items. He correctly rejected all but one (143/144) of the unrelated picture foils with printed words and all unrelated pictures with auditory words. In contrast, he frequently failed to reject semantically related pictures with auditory words (58/144 items) or printed words (39/144). Thus, although an item was scored as wrong if he made an error with one or more of the three picture trials, the vast majority of his total errors, summarised in Table 2, represent items for which he accepted both the correct picture and a semantically related foil (recall that the three pictures were not presented sequentially with a given word).

In writing tasks, semantic errors were slightly less frequent and constituted a lower percent of the total *errors* (Table 4). This difference occurred because a substantial number of KE's spelling errors on these lists were not words. Many of his nonword responses were very likely to have been misspelled semantic errors, but were not initially scored as such because they varied from words by more than one letter. When words misspelled as nonwords were re-scored as the most likely intended word (for example, "shark" → *alligate* as a semantic error; "elephant" → *elephuse* as a correct response) or as unrecognisable (e.g. "walrus" → *naser*), the distributions of errors in writing tasks were on par with oral production and word/picture verification tasks: out of 150 errors on written naming of pictures in the *combined* lists (1a, 1b, and 2), 84.7% (127) were semantic errors (compared to 84.5% of errors in oral naming and 79.4% in oral reading), 4.0% (6) were unrecognisable responses, and 11.3% (17) were omissions. Of the 139 errors in writing to dictation on the combined lists, 80.6% (112) were semantic errors, 10.1% (14) were unrecognisable responses, and 9.4% (13) omissions.

The vast majority of KE's semantic errors were within-category ("co-ordinate") errors, of the type *jacket* → "pants". The percentage of co-ordinate errors was equally high across all modalities: 80% of all semantic errors in oral picture naming; 83% in written naming; 83% in writing to dictation; and 91% in oral reading (from List 1a). Only one superordinate error ("ostrich" → *bird*) and one synonymic error (*stomach* → "belly") were recorded in KE's responses on this list. Responses of the latter type were not considered errors in picture naming tasks. Associative errors were occasionally made in each task, including: *bench* → "church" in oral naming; stomach → *belt* in written naming; *stove* → "kitchen" in oral reading; and "lips" → *desire* in writing to dictation (additional examples of responses are found in Appendix B). In summary, KE's lexical errors were very similar in both quantity and quality across input and output modalities, and were almost exclusively of the semantic co-ordinate type.

[7]Chi-square tests for this and the preceding analysis were based on number (frequency) of occurrences of error versus correct on each task, and semantic error versus absence of semantic error (correct *or* other error) on each task, respectively.

TABLE 4
Distribution of KE's Errors (Collapsed Lists)

	Semantic	*Visually Similar Word*	*Nonword Misspelling/ Neologism*	*Other*	*No Response "Don't Know"*	*Total*
Oral Naming	126(84.6)	0	1(0.7)	1(0.7)	21(14.1)	149
Written Naming	107(71.3)	1(0.7)	22(14.7)[a]	3(2.0)[b]	17(11.3)	150
Oral Reading	116(81.7)	2(1.4)	0	1(0.7)[b]	23(16.2)	142
Writing to Dictation	84(60.4)	2(1.4)	33(23.7)[a]	7(5.0)	13(9.4)	139
Auditory Comprehension	77(96.3)	0	N/A	3(3.8)[c]	0	80
Reading Comprehension	54(79.4)	1(1.5)	N/A	13(19.1)	0	68

[a]Includes misspelled, possible semantic errors (e.g. crab → (clam) → clim; giraffe → (zebra) → zegar).
[b]Includes possible visual → semantic errors (waist → [wrist] → watch) and semantic → visual errors (cheek → [rouge] → rug).
[c]Rejection of correct word/picture matches.

Discussion of Error Types. In the types of processing models that have been proposed for reading and spelling, semantic errors might arise from damage to (at least) one of two possible levels: the semantic system or either of the output lexicons (phonological or orthographic) (see Caramazza & Hillis, in press a, for discussion). Although many authors have simply assumed that semantic paraphasias and paragraphias arise from damage in processing semantic representations (e.g. Assal, Buttet, & Jolivet, 1981; Friedman & Perlman, 1982), semantic errors may also arise from a deficit in retrieving lexical forms for output: when the target entry in an output lexicon is inaccessible, a semantically related output representation may be produced if it is partially activated by an intact semantic representation (see Caramazza, 1986). For instance, the semantic representation of CHAIR could partially activate the lexical entries "bed", "sofa", and "bench" as well as "chair"; and subsequently the most easily accessible entry (e.g. the one with the lowest threshold of activation in the output lexicon) could be produced if the phonological representation of "chair" were inaccessible[8].

Semantic errors on the word/picture matching tasks, however, cannot easily be attributed to the impairment of output lexicons (unless one assumes that correct performance on these tasks is normally accomplished by generating a word response to the picture and then testing for a match between the generated response and the word stimulus). Thus, the origin of KE's comparable pattern of semantic errors across lexical tasks is most likely to be the semantic component. Indeed, the striking homogeneity of his performance across reading, naming, writing, *and* comprehension tasks may best be explained by postulating damage to a single semantic system common to all of these cognitive processes—a proposal that contrasts with the possibility raised by Warrington and Shallice (1979, p. 59) of "the dissociation of meaning systems corresponding to the written and spoken word".

Further evidence that KE's performance reflects damage that is relatively restricted to a single (semantic) mechanism in all lexical processing tasks is provided by measures of consistency across tasks. We turn to this evidence next.

Analysis 2: Determination of Task Interdependence

If KE's errors arose from damage to different processing components, performance (semantic errors) in one modality should be independent of performance in modalities that involve different processing mechanisms. For example, the probability of accepting a semantic foil for a given item in word/picture verification would be independent of the probability of producing a semantic paragraphia for that item in writing to dictation if damage to different components of processing were responsible for errors in the two tasks. If, on the other hand, the errors occur as the result of damage to a single semantic mechanism, the probabilities of making semantic errors on a particular item across various tasks should all be *inter*dependent. That is, an item that elicits a semantic error in one task should be likely to elicit semantic errors in the other tasks as well. This

[8]Another possible source of semantic errors is an output deficit that leads the patient to supply a related word *deliberately* to demonstrate comprehension of the task; but this explanation is unsupported in KE's case, because he gave no indication that he was aware of his semantic errors.

expectation is derived from the fact that the damage affecting performance in the various tasks is presumably the same and should, therefore, result in similar performance across tasks. To evaluate this hypothesis of task interdependence, we counted the number of semantic errors made by KE on each item across tasks (separately for each list). For List 1b, for example, we compared the observed item distribution as a function of the number of tasks on which the item resulted in a semantic error (i.e. the number of items that resulted in no semantic errors, a semantic error in one task, two tasks, etc.) with the item distribution expected if there were no task interdependence[9]. If the performance across tasks were dependent on a common factor, the two distributions should be significantly different. This prediction should be most obvious for the two ends of the distribution: a larger proportion of items than predicted by chance should give rise to no semantic errors at all, or to semantic errors on many tasks[10].

The results clearly suggest a strong interdependence among tasks in the production of semantic errors. For all three lists, the observed and expected distributions were significantly different, in the predicted direction ($\chi^2_{4\text{–}8} > 100$; $P < 0.0001$ for all lists; Table 5).

It was also observed that a given item sometimes elicited the same semantic error across modalities. For instance, KE wrote *tiger* in response to the dictated word and the picture of a leopard; he said "tiger" in reading *leopard* and naming a leopard; and he accepted the word *tiger* (and "tiger"—spoken) as the name for a picture of a leopard. This uniformity

[9]Values expected if there were no task interdependence were calculated by summing all permutations that would result in semantic errors on the given number of tasks. For example, the formula used to compute the expected number of items that would result in two semantic errors if the errors were task-specific was:
$(P1 \times P2 \times Q3 \times Q4 \times Q5 \times Q6) + (P1 \times Q2 \times P3 \times Q4 \times Q5 \times Q6) +$
$(P1 \times Q2 \times Q3 \times P4 \times Q5 \times Q6) + (P1 \times Q2 \times Q3 \times Q4 \times P5 \times Q6) +$
$(P1 \times Q2 \times Q3 \times Q4 \times Q5 \times P6) \ldots \times 144$ where:
P1 = probability of a semantic error in task 1 (oral naming);
P2 = probability of a semantic error in task 2 (written naming);
Q1 = probability of no semantic error in task 1 (oral naming);
Q2 = probability of no semantic error in task 2, and so on.

[10]More specifically, if different representations were recruited in different tasks with a given item, then we would expect there to be few items that failed to elicit a semantic error on any of the 6 to 8 tasks (when about 30–40% of his responses in all tasks were semantic errors). If, on the other hand, the separate tasks were to involve a common semantic system, then there might be a substantial subset of items that each consistently recruit an unimpaired representation and result in no semantic errors on any of the tasks. Furthermore, according to the account of KE's performance that we will offer—that specific semantic representations are impoverished—those items that recruit *impaired* representations should result in semantic errors on several tasks and, by chance (depending on the number of output representations that are compatible with the impaired semantic information), correct responses on other tasks.

TABLE 5
Distribution of Items as a Function of the Number of Tasks on Which the Item Resulted in a Semantic Error

No. of Tasks that Elicited Semantic Errors	*No. of Items (%) Observed*	*No. of Items (%) Expected*[a]
For List 1a: 0	72(50.0)	37.3(25.9)
1	20(13.9)	60.4(41.9)
2	20(13.9)	36.1(25.0)
3	23(16.0)	9.4(6.5)
4	9(6.3)	0.9(0.6)
	$\chi^2_4 = 121.5; P \leqslant 0.0001$	
For List 1b: 0	46(31.9)	11.2(7.7)
1	17(11.8)	35.9(24.9)
2	20(13.9)	47.7(33.1)
3	27(18.8)	33.4(23.2)
4	16(11.1)	13.0(9.0)
5	13(9.0)	2.7(1.8)
6	5(3.5)	0.2(0.2)
	$\chi^2_6 = 211; P \leqslant 0.0001$	
For List 2: 0	17(36.2)	3.4(7.2)
1	2(4.3)	10.6(22.5)
2	3(6.4)	14.4(30.5)
3	3(6.4)	11.2(23.8)
5	5(10.6)	1.7(3.6)
6	6(12.8)	0.3(0.6)
7	3(6.4)	0.05(0.1)
8	2(4.3)	0.0(0.0)
	$\chi^2_8 = 40.01; P < 0.0001$	

[a]Based on error rate in each task, assuming no interdependence (see footnote 9).

was not consistent for all items. For example, the item *arm* elicited "ear" in oral reading, "finger" in verbal picture naming, *leg* in written naming, and *hand* in writing to dictation. Nevertheless, KE showed a tendency to produce the identical error response across 2 or more tasks. For example on List 1a, 20 items elicited the same error in 2 tasks; 11 items elicited the same error in 3 tasks, and 2 items elicited the same error in all 4 tasks. The probability of selecting the identical semantic error from independent sources (e.g. separate semantic systems) just by chance cannot be calculated, because we cannot determine exactly how much or what sort of semantic information is spared; but the chance level is certainly extremely small.

Discussion of Task Interdependence. If an item elicited a semantic error on one task, there was a highly significant probability that it would

elicit semantic errors on other tasks with different input and/or output modalities. These results make it difficult to maintain a hypothesis of multiple sources of semantic errors. Specifically, the obtained distributions of errors were inconsistent with the hypothesis that the probability of producing a semantic error was primarily dependent either on the output or the input modality implicated in a task. For instance, for List 1a we found a disproportionate (i.e. higher than expected) number of items with semantic errors in zero and three tasks (see Table 5), although two tasks required oral and two required written responses, and two tasks used picture stimuli and two used lexical stimuli. Along with the strong interdependence among all of the tasks, these results support the hypothesis that damage to a single cognitive component is responsible for the observed performance across the various experimental tasks.

Analysis 3: Intra-task Versus Inter-task Item Consistency

An additional prediction follows if we assume a common source of errors: variability in the production of semantic errors in response to a particular item should be no higher across modalities than within a modality. That is, retesting the same task—within a modality—or administering the same items in different tasks—across modalities—should be equivalent, because the tasks are affected by the same source of difficulty. On the other hand, if semantic errors in different tasks result from damage to different processing components (or semantic systems), there would be separate sources of variability for the error responses. We would then expect greater consistency between repeated tests of any given task than between tests of different tasks. That is, if there were multiple deficits, within-modality testing would repeatedly tap one source of variability, whereas across-modality testing would tap different sources of variability. To investigate this prediction, inter-task consistency was compared to intra-task (test-retest) consistency.

Item-by-item, test-retest consistency was calculated for those tasks of List 1a that were repeated in List 1b. The same was done for the tasks of List 2 that were administered twice. Measures of consistency were calculated for: (1) the percentage of items responded to with the same accuracy (correct both times or incorrect both times) on the two administrations of any task and (2) the percentage of items that elicited the identical semantic error on retesting. For intertask consistency, both measures were calculated for every pairing of tasks on List 1 (a & b) and every pairing on List 2.

The levels of item agreement for inter-task and intra-task analyses were nearly identical, both in terms of accuracy (item correct in both tests or incorrect in both) and in terms of the specific semantic error produced. For instance, for the task of oral naming on List 1, test-retest agreement on accuracy was 66.7% (96 items). That is, 96 of the 144 items on the list were responded to either correctly or incorrectly on both administrations of the task. The item-by-item agreement between accuracy of oral naming and accuracy of other tasks averaged 74.8% (mean = 107.7/144 items), which is based on: 79.9% (115/144) agreement with written naming; 72.9% (105/144) agreement with oral reading; and 71.5% agreement (103/144) with writing to dictation. There were no significant differences between test-retest agreement and inter-task agreement for any of the tasks ($\chi^2_3 = 5.9$; n.s.). In other words, item consistency across two administrations of the same task was no greater than item consistency across tasks. The result was obtained for all modalities (Table 6). Test-retest consistency was also significantly above the chance level of 50% for each task ($\chi^2_1 = 7.56$; $P < 0.01$ for oral naming; $\chi^2_1 = 17.06$; $P < 0.0001$ for written naming; and $\chi^2_1 = 13.01$; $P < 0.0005$ for oral reading and dictation). Above chance item consistency *between* tasks was demonstrated in the previous analysis[11]. Furthermore, the number of items that elicited the same semantic error on retesting was very nearly identical to, or lower than, the mean number of items that elicited the same semantic error from task to task. Thus, the name given in response to a particular item could predict the name given to that item on retesting of the same task no better than it could predict the name given to that item in a different task.

Because word/picture matching tasks were not tested for List 1a, we could not compare consistency between performance on these tasks and performance on the other tasks in order to evaluate test-retest consistency. However, it was possible to show that item agreement between each of the word/picture verification tasks and each of the other tasks was comparable to levels of agreement reported earlier. Item agreement on accuracy between the auditory word/picture verification task and the other tasks in List 1b was: 66% agreement with oral naming (95 items either incorrect on both tasks or correct on both tasks), 61.8% (89 items) with written naming, 68.1% (98) with oral reading, 65.3% (94) with dictation, and 68.8% (99) with the printed word/picture verification task. Item agreement on accuracy between the printed word/picture verification task and the other tasks in List 1b was: 67.4% (97 items) with oral naming, 62.5% (90) with written naming, 67.4% (97) with oral reading, and 65.3% (94) with dictation. On List 2, item consistency between the auditory word/picture verification task and the other tasks ranged from 72.3% (34 items), with tactile naming, to 78.7% (37 items) with written naming; and item consistency between the printed word/picture task and the other tasks ranged from 68.1% (32 items) with oral naming to 78.7% (37 items) with written

[11]The finding of above chance levels of test-retest or intertask consistency is not critical to our interpretation of the results, since we will show that inconsistent performance might well result when impaired semantic information, which is equally compatible with the correct response and semantically related items, serves to activate entries in the output lexicons. But we would expect a higher than chance-level consistency if there were some items for which semantic information were intact, as indicated by the high level of accuracy on certain categories of words. Therefore, we point out that our measures of consistency meet criteria discussed by Coltheart and Funnell (1987) for valid measures of consistency in lexical processing tasks: (1) the overall probability of successful lexical processing was around 0.4 to 0.6, given that item consistency that occurred just by chance would *not* respect category boundaries; and (2) the chance level of a correct response without lexical processing is near zero for all the tasks except word/picture verification (refer to their paper for rationale behind these criteria).

TABLE 6
Intra-task and Inter-task Item Consistency for Same Accuracy

	List 1		*List 2*	
	Test-Retest Consistency N(%)	*$\bar{X}$ Intertask Consistency N(%)*	*Test-Retest Consistency N(%)*	*$\bar{X}$ Intertask Consistency N(%)*
Oral Naming (Pictures)	96(66.7)	107.7(74.8)	26(55.3)	29.8(63.4)
Written Naming	107(74.3)	108.3(75.2)	35(74.5)	30.8(65.5)
Oral Reading	103(71.5)	95.3(66.2)	29(61.7)	29.8(63.4)
Writing to Dictation	103(71.5)	100.0(69.4)	31(66.0)	27.3(58.1)
Tactile Naming	—	—	26(55.3)	29.8(63.4)

TABLE 7
Intra-task and Inter-task Item Consistency for Same Semantic Error

	List 1		*List 2*	
	Test-Retest Consistency N(%)	*$\bar{X}$ Intertask Consistency N(%)*	*Test-Retest Consistency N(%)*	*$\bar{X}$ Intertask Consistency N(%)*
Oral Naming (Pictures)	10(6.9)	10.3(7.2)	4(8.5)	7.0(14.9)
Written Naming	11(7.6)	10.3(7.2)	1(2.1)	1.8(3.8)
Oral Reading	4(2.8)	5.0(3.5)	2(4.3)	3.3(7.0)
Writing to Dictation	3(2.1)	5.7(4.0)	0	1.5(3.2)
Tactile Naming	—	—	5(10.6)	7.5(16.0)

naming and dictation. Item agreement between the two verification tasks on List 2 was 76.6% (36 items)[12].

Discussion of Item Consistency. The obtained equivalence in item agreement between the two word/picture verification tasks, between each of these and the verbal and written tasks, and between each pair of verbal and written tasks, provides perhaps the strongest evidence so far for a single source of errors in all of the tasks tested. If damage to different mechanisms (or distinct semantic systems) were responsible for errors in different tasks, we would have expected higher item agreement within than between tasks. However, the results show quite the opposite: item consistency across tasks was as high as item consistency within tasks. This pattern of performance across modalities could only be possible in the case of separate loci of deficits in lexical processing if brain damage could affect equally the same items in each of the damaged components.

It is not inconceivable, however, that some items might in fact be particularly vulnerable, or invulnerable, in several components of the lexical system. To illustrate, if KE's lexical processing were affected by word frequency, then the highest frequency items might be the most available items for processing at several levels. But we have already reported that frequency was not a significant factor in KE's success in lexical tasks. However, there might be other lexical variables that influence processing at several levels. For example, if KE were to be very familiar with donkeys and raccoons (but not with other animals), representations for donkeys and raccoons might be differentially preserved in multiple lexical and/or semantic components. Therefore, we attempted to explore the possibility that KE's homogeneous performance was attributable to a disproportionate familiarity with, or otherwise "sparing" of, certain items.

Analysis 4: Previously Produced Erroneous Responses as Stimuli

If highly familiar items have relatively high accessibility in several processing mechanisms, these items might be produced as responses more often than other items. Additionally, error rates in response to these items would be low. To test this latter possibility, we presented stimulus items that were previously given as erroneous responses. All picturable words KE had incorrectly produced as responses in previous experiments were presented as stimuli in the same task. For example, in oral naming of a pictured turtle, he said, "frog" on the first test; so in this experiment, a picture of a frog was presented. Procedures were equivalent to those followed for the other lists.

[12]We are grateful to Max Coltheart for suggesting this analysis.

KE's error rates with these stimuli were comparable to his error rates with the initial stimuli for each task, when the rates of either total errors or semantic errors were compared. There was a nonsignificant trend toward lower total errors in response to words he had given as errors ($\chi^2_1 = 0.098$ to 2.18; $P > 0.05$), but the rate of semantic errors was nearly identical (Table 8). For instance, the semantic error rate for oral reading was 31.4% on this test, compared to his previous 30.6% ($\chi^2_1 = 0.016$; n.s.). Sometimes his errors indicated the reverse semantic confusion. For instance, a picture of a tiger elicited the oral name, "lion"; and a picture of a lion elicited the oral name, "tiger". Generally, however, his errors did not respect any obvious pattern.

Discussion of Analysis 4. These results indicate that the items KE produced as error responses were neither more "intact" nor generally more available than the stimulus items that elicited them. Therefore, the hypothesis that high inter-task consistency could be explained on the basis of familiarity with particular items is not supported.

These results are also relevant to the question of whether: (1) the semantic co-ordinate errors that KE produced in all tasks constitute items that have relatively spared representations in the semantic system, which are thus activated in place of the target representations, or (2) these responses merely represent a random response within the set of words that satisfy the (underspecified) semantic information that is activated by the stimulus. In the latter case, it is assumed that the semantic information activated by a stimulus is insufficient to determine a specific response, but it is sufficient to restrict responses to items from a specific category. These possibilities may be evaluated by considering KE's performance with the items he produced as responses. If the responses produced by KE consti-

TABLE 8
Rate of Semantic Errors

	Initial Stimuli	*Prev. Produced Semantic Error*	χ^2_1
Oral Naming	34.0(49/144)	26.3(10/38)	0.39 n.s.
Written Naming	28.5(41/144)	33.3(10/30)	0.10 n.s.
Dictation	20.8(30/144)	16.7(5/30)	0.07 n.s.
Oral Reading	30.6(44/144)	31.4(11/35)	0.02 n.s.
Auditory Word-Picture Matching	40.3(58/144)	34.5(20/58)	1.43 n.s.
Printed Word-Picture Matching	27.1(39/144)	28.2(11/39)	0.03 n.s.

tute items with spared semantic representations, then we would have expected him to perform well on testing of these items. By contrast, the obtained equivalence in performance on these items and on the original stimuli is consistent with the hypothesis that the responses produced by KE merely reflect a random selection from a set of responses constrained by partial information.

Analysis 5: Intra- Versus Inter-task Consistency Across Semantic Categories

In the previous analysis, we failed to uncover evidence that particular items within a semantic category were spared. However, we have yet to consider all of the factors that determine the probability that KE would make a semantic error in processing an item. We have shown that although frequency does not affect performance, the concreteness value of an item is a major determinant of the probability that he would make a semantic error: very many more semantic errors were made to concrete than abstract words. Recall that abstract words resulted primarily in omissions ("don't know" responses) or, less frequently, unrelated responses (e.g. pursuit → "pamp" [pæmp]). Another dimension to consider is the semantic category of an item. There is now a substantial literature showing that damage to the semantic system may affect semantic categories to different extents—sparing some, damaging others (Hart, Berndt, & Caramazza, 1985; Silveri & Gainotti, 1988; Warrington & McCarthy, 1987; Warrington & Shallice, 1984). If KE were to show strong variation in performance across semantic categories, we could exploit this situation to evaluate further the thesis that he has selective damage to a central semantic processing system. That is, we could compare semantic category differences in error rates *within* a modality to category differences in error rates *across* modalities. This analysis was motivated, in part, by the claim of Warrington and Shallice (1984) that dissociations between categories that are relatively specific to one stimulus modality would constitute counter-evidence to the hypothesis that the patient has damage to a single semantic processing component. Thus, for example, if more semantic errors were made in response to animals than to furniture in one modality, but not in another modality, it could suggest (though not necessarily require) that separate sources of damage gave rise to the pattern of errors.

Comparisons were made for List 1 only, since there was only a small number of stimuli in each category of List 2. For each of the six tasks in List 1b, the categories were rank ordered according to the percentage of semantic errors produced (Table 9) and total errors produced (Table 10). It is clear from inspection of the tables that there is greater consistency

TABLE 9
Rank Order in Percent of Semantic Errors by Category

Total	*Verbal Name*	*Written Name*	*Oral Reading*	*Dictation*	*Auditory Word/ Picture Verif.*	*Printed Word/ Picture Verif.*
body parts 60.0	body parts 65.0	furniture 57.9	body parts 75.0	furniture 36.8	body parts 75.0	body parts 60.0
furniture 45.6	clothing 64.3	body parts 50.0	clothing 42.9	body parts 35.0	water animals 46.2	furniture 42.1
clothing 41.7	furniture 57.9	clothing 50.0	furniture 42.1	transport 33.3	furniture 36.8	clothing 28.6
water animals 35.9	water animals 46.2	water animals 46.2	transport 41.7	water animals 30.8	clothing 35.7	transport 25.0
transport 34.7	transport 33.3	transport 41.7	other animals 40.0	birds 30.8	transport 33.3	fruits 18.2
birds 25.6	birds 30.8	birds 38.5	water animals 30.8	clothing 28.6	birds 30.8	vegetables 18.2
other animals 25.0	other animals 30.0	other animals 20.0	fruits 18.2	other animals 20.0	other animals 30.0	water animals 15.4
fruits 21.2	fruits 27.3	fruits 18.2	birds 15.4	fruits 18.2	fruits 27.3	other animals 10.0
vegetables 15.2	vegetables 9.1	vegetables 9.1	vegetables 9.1	vegetables 18.2	vegetables 27.3	other foods 9.1
other foods 7.6	other foods 0	other foods 0	other foods 9.1	other foods 18.2	other foods 9.1	birds 7.6

between different modalities than between different categories within a single modality.

In contrast to the wide variability between categories within each modality (e.g. 0–65% errors for oral naming), the rank order of the categories was very similar across modalities (for both semantic error and total error rates). For instance, the categories of body parts, furniture, and

TABLE 10
Rank Order in Percent of Any Errors by Category

Total	*Verbal Name*	*Written Name*	*Oral Reading*	*Dictation*	*Printed Word/ Picture Verif.*	*Auditory Word/ Picture Verif.*
body parts 63.3	body parts 65.0	clothing 64.3	body parts 80.0	furniture 47.4	body parts 60.0	body parts 75.0
furniture 49.1	clothing 64.3	furniture 63.2	clothing 42.9	water animals 46.2	furniture 42.1	water animals 53.9
clothing 45.2	furniture 63.2	water animals 61.5	furniture 42.1	body parts 45.0	clothing 28.6	furniture 36.8
water animals 44.9	water animals 53.9	body parts 55.0	transport 41.7	other animals 40.0	transport 25.0	fruits 36.4
transport 34.7	fruits 36.4	birds 46.2	water animals 38.5	birds 38.5	fruits 18.2	clothing 35.7
other animals 33.3	other animals 35.0	transport 41.7	fruits 36.4	veget-ables 36.4	veget-ables 18.2	transport 33.3
birds 30.8	transport 33.3	other animals 35.0	other animals 35.0	clothing 35.7	water animals 15.4	birds 30.8
fruits 30.3	birds 30.8	fruits 27.3	birds 30.8	transport 33.3	other animals 15.0	other animals 30.0
veget-ables 22.7	veget-ables 18.2	veget-ables 27.3	veget-ables 9.1	fruits 27.3	birds 7.7	veget-ables 27.3
other foods 7.6	other foods 0	other foods 9.1	other foods 9.1	other foods 18.2	other foods 0	other foods 9.1

clothing were associated with the highest rates of semantic errors in five out of the six tasks. In the sixth task, auditory word/picture verification, these categories represented three of the four highest semantic error rates, along with the category, "water animals". The categories of "fruits" and "veget-ables" were toward the lowest in rank order, regardless of modality, while "transportation" was uniformly in a middle rank across tasks.

It is worth noting that the three categories that yielded the highest semantic (and total) error rates were from the group of categories whose members had the highest word frequency (of occurrence in print). Yet, another high-frequency category, "foods" (excluding fruits and veget-ables), elicited the fewest semantic errors in five of the six tasks, and only one semantic error in the remaining task. Therefore, differences between categories cannot be attributed to word frequency.

Two-way analysis of variance, with frequency of semantic errors as the dependent variable, confirmed that there were only marginally significant differences between tasks of modalities ($F_{5,45} = 2.69$; $P < 0.05$), whereas there were highly significant differences between categories ($F_{9,45} = 15.4$; $P < 0.0001$) in each modality. The variability between categories was significantly higher than the variability between modalities ($F_{9,5} = 5.74$; $P < 0.03$).

Results of the same analysis performed on the data from List 1a (with only 4 tasks) were comparable to those just reported: for List 1b, "body parts" elicited the highest rate of semantic errors (overall 61.9%) and total errors (overall 72.6%) for all tasks, while "vegetables" and "other foods" yielded the lowest error rates across modalities (overall 16.7% and 6.3% semantic errors, and 25.0% and 20.8% total errors, respectively).

Discussion of Category Consistency Across Modalities. There clearly is evidence that the semantic deficit in KE affects various semantic categories differentially. However, it would seem that the damage concerns a single semantic component involved in all the tasks tested. Warrington and Shallice (1984) have argued that greater consistency of performance across categories within a modality than between modalities would undermine the thesis of a unitary semantic system. By their argument, our contrasting finding of greater consistency between modalities than between categories within a modality cannot be explained by an account that postulates damage to different lexical processing components (or a different semantic system) for lexical tasks in different modalities. Such an account would require each lexical processing component (or semantic system) to be damaged in such a manner as to produce the same pattern of errors across categories for all tasks—a rather unlikely proposition.

Performance on Sorting Tasks

Results thus far reported constitute clear evidence of damage to a single semantic mechanism in lexical processing. We have not yet considered the issue of whether or not this damaged semantic system is specific to lexical processing. It was noted earlier that when asked to "mime the meaning" of pictures and words KE never produced incorrect gestures to pictures, although he often produced ambiguous ones. However, he did produce a number of incorrect gestures to word stimuli. In order to examine the possibility that KE had more intact semantic representations of pictures than of words, a number of nonlexical, "visual" semantic tasks were administered.

KE was asked to sort the 144 picture stimuli from List 1 into appropriate categories. His performance was flawless. However, he was also able to sort the corresponding printed words into categories with a high level of accuracy—99%; 142/144 correct. These results suggest that he was able to identify sufficient information to identify the superordinate category for *both* word stimuli and pictures that elicited semantic (primarily co-ordinate) errors in the other experimental tasks. Thus, the inference of a more intact semantic representation of pictures than of words cannot be sustained on the basis of accurate categorisation.

We also found that when KE was given the 46 pictures of animals from List 1, he was able to sequence them adequately, by stacking them according to the size of the actual animal (the pictures themselves were all about the same size, not proportional to actual sizes). Although his responses were not compared to actual norms for the animals, they seemed reasonable to the experimenter (AH), who is unsure how to order, for example, octopus, walrus, and shark. Further, KE was able to colour accurately with coloured pencils the black and white line drawings of the 46 animals. Given the evidence that KE obtained sufficient information from both pictures and words to sort them by superordinate category, his plausible performance on the size-sequencing and colouring tasks may also reflect such partial semantic information. For example, adequate information to identify the category of animals (say, "large animals to fear" versus "little animals to pet") could support plausible ordering by size.

Regrettably, we did not ask KE to sequence or identify the colour of items with word stimuli, but there is some evidence that his knowledge accessed by words would have supported credible performance on these tasks: his semantic errors in response to words in dictation and oral reading usually referred to animals approximately the same size and colour as the target (e.g. *leopard* → "tiger", *fox* → "dog"). Clearly, this correspondence might result from accessing semantic information sufficient for categorisation. However, even if it could be shown that the size-sequencing and colouring results indicate relatively intact access to perceptual attributes from some of the pictures that elicited semantic errors on lexical tasks, the implications of these results for issues about semantic structure and processing are far from obvious, as we discuss more fully in the General Discussion section of this paper.

Summary of the Results

The following brief review summarises the results of this investigation of the patient's responses to items presented in three different modalities of input and requiring three modalities of response.

1. An error analysis of KE's responses revealed that the predominant error type was semantic. Semantic errors occurred with essentially the same frequency across all modalities of input and output. We localised KE's functional deficit to the semantic system rather than at the level of the two output lexicons, because: (i) he showed a similar pattern of errors on the word/picture verification tasks, which do not involve the output systems; and (ii) the homogeneity of his performance contraindicates separate loci of damage.
2. A determination of task interdependence indicated that the probability of making a semantic error on a given item was significantly different to what would be expected if there were no interdependence between tasks. More importantly (since most competing hypotheses would predict interdependence among two or more of the tasks, depending on the number of proposed semantic systems and the basis for distinguishing them), the distributions of items that elicited semantic errors were inconsistent with the hypothesis of separate sources of errors for separate modalities of input (picture versus words) or output (lexical versus word/picture verification).
3. A comparison of item consistency across tasks with test-retest consistency indicated no significant differences between these two measures of response reliability. Hence, the accuracy of response given to a particular item could predict the response to that item in a different task (different input and/or output modality) as well as it could predict the response to that item in retesting of the same task. Nor was there better item agreement between the two tasks of word/picture verification than between these tasks and the tasks that require lexical output. Furthermore, there was no indication that this consistency across different modalities of input and output resulted from the fact that certain items were for some reason less vulnerable to damage than others. When responses that KE had produced as errors were administered to him as stimuli, the same pattern of responding as that observed on the two experimental lists emerged.
4. A fine-grained analysis of performance by semantic categories revealed significant differences in semantic error rates across different categories within each modality of input or output. The degree to which a category was affected was not predicted by the mean frequency of the items in the category, indicating that the locus of the errors was in a system for which frequency is not a major factor. Further, the rank ordering of performance by category was generally maintained across input and output

modalities. It is highly unlikely that a series of deficits across a number of lexical components or semantic systems would have affected semantic categories similarly.

5. KE performed very well in tasks requiring the categorisation of objects and words, the sorting of objects by size, and the colouring of black and white pictures of objects.

GENERAL DISCUSSION

We have described the impaired performance of patient KE, who produced a comparable pattern of semantic errors in repeated administrations of tasks that involved stimuli presented in different input modalities (written words, auditory words, pictures, objects, tactually presented objects) and tasks that required a response in a number of output modalities (writing, speaking, or verification). The pattern of associated deficits observed for KE is most simply explained by proposing damage to a single semantic processing mechanism shared by all lexical processes, regardless of modality of input or output. The homogeneity of KE's performance on specific items and semantic categories across all modalities of input and output would be very difficult to explain by proposing damage to separate mechanisms or separate semantic systems associated with different modalities of lexical representation—phonological versus orthographic. A multiple deficit account would require that each of the putative systems or mechanisms be damaged in an identical manner. These results represent strong evidence for the existence of a modality-independent semantic mechanism common to all lexical processes. As such, they provide support for the general type of functional architecture shown in Fig. 1, in which there is one system of meaning that links input and output representations in reading, spelling and naming.

Of course, striking dissociations between modalities have also been reported, most of which have been interpreted as resulting from selective disruptions of input or output processes (e.g. Bub & Kertesz, 1982; Caramazza & Hillis, in press a; Ellis, Miller, & Sin, 1983; Gainotti, Silveri, Villa, & Miceli, 1986; Riddoch & Humphreys, 1987). In addition, a few cases showing a dissociation between comprehension (impaired) and reading or writing (relatively intact) have been presented as evidence for "direct" lexical reading and/or writing without semantic mediation. If it were to be the case that *lexical* output in these tasks does not require semantic mediation, then selective impairment of the semantic component in lexical processing would be expected to result in more errors in naming and comprehension tasks than in oral reading and dictation (or, if one also proposed a direct, nonsemantic naming "route" (e.g. Ratcliff & Newcombe [1982], comprehension should be most impaired). To account for KE's pattern of performance we would then have to postulate damage to the nonsemantic lexical mechanisms, in addition to the proposed loci of damage—that is, in addition to damage to the semantic component and the nonlexical spelling and reading mechanisms. However, we do not think that this qualification is necessary, because the evidence that has been presented in support of the existence of mechanisms for nonsemantic, lexical reading and writing is unconvincing. Next we briefly outline an alternative account of the existing data (see Hillis & Caramazza, Note 2, for further discussion).

Patients WLP (Schwartz et al., 1980), HTR (Shallice et al., 1983), MP (Bub et al., 1985) and KT (McCarthy & Warrington, 1986) all read fluently and fairly accurately, despite poor comprehension. Although they each showed strong effects of regularity on reading performance, it was argued in each case that the patient did not rely solely on nonlexical, orthography-to-phonology mapping procedures, because he or she could read some irregular words correctly despite very impaired comprehension. The conclusion that these patients read without any semantic knowledge is, however, unjustified. In every case, comprehension was judged to be nearly abolished on the basis of the observation that the patient made frequent errors in distinguishing between the referent of a word and semantically related items (e.g. as on the Peabody Picture Vocabulary Test). However, poor performance in discriminating among semantically related items does not imply total failure to activate any semantic information about the items in question. Thus, it remains possible that the patients were able to obtain *some* semantic knowledge from printed words, in addition to information about phonological segments that they were able to compute from sublexical, orthographic structure. These two sorts of information could serve to "block" semantic paralexias. In support of this hypothesis, Hillis and Caramazza (Note 2) found that a patient, with the general pattern of performance reported for "nonsemantic" readers, correctly and fluently read all words for which he demonstrated *some* comprehension (in definitions and categorisation), and misread only irregular words for which he showed no understanding at all. Thus, his partially preserved semantic system apparently operated in concert with his intact nonlexical mechanisms for converting sublexical grapheme sequences into phoneme sequences, to activate correct entries in the output lexicon. Reported indications of present, but reduced, comprehension of words in the cases cited here suggests that their reading patterns might also reflect such an interaction between lexical-semantic and nonlexical mechanisms.

A comparable account of relatively good writing with impaired semantic information can be formulated, without postulating a nonsemantic lexical route for spelling. Most of the relevant cases evidenced high reliance on phonology-to-orthography conversion procedures (see Baxter & Warrington, 1987; Goodman & Caramazza, 1986b; Patterson & Shewell, 1987), as well as some (if not perfect) comprehension of spoken words. Even in cases where nonlexical spelling mechanisms were impaired (e.g. Kremin, 1987), it is apparent that such procedures were sufficient to "block" semantically related words activated by a partial semantic representation. Consistent with this interpretation, nearly all of the words spelled correctly by Kremin's patient were reportedly understood perfectly or "a bit but not quite". Thus, the evidence and the arguments in support of the proposals for nonsemantic lexical procedures for reading and spelling would seem to be less than compelling. In view of this conclusion, KE's comparable performance across all lexical tasks does not undermine the hypothesis that his performance reflects selective damage to the semantic component in lexical processing (although he also clearly had impairments in nonlexical reading and spelling mechanisms, and perhaps to other nonlexical cognitive mechanisms outside the range of interest of this study).

We have argued that the pattern of results reported for KE is most readily interpreted as reflecting selective damage to the semantic component engaged in lexical processing. The arguments offered in support of this hypothesis are based on minimal assumptions about the representation and processing structure of the semantic component: we have assumed that the semantic component represents information in terms of sets of predicates referring to perceptual, functional, and relational attributes of a term. We have made the further assumption that damage to the semantic system may selectively affect only *some* of the predicates, resulting in an incompletely specified semantic representation for a term. With these assumptions, it has been possible to account for KE's complex performance by assuming that he suffered selective damage to a single semantic system which is necessarily engaged in the normal execution of the various tasks described in this report. Selective damage to this system should result in comparable rates and types of errors in all tasks involving semantic processing—the reported pattern of performance.

As indicated in the Introduction, however, there is disagreement on the issue of whether we should think of semantic processing as involving a single semantic system or several modality-specific semantic systems. This issue has recently been the focus of much discussion in the cognitive neuropsychological literature (see Job & Sartori, 1988). On one side of the debate are those who maintain that there is only one store of semantic knowledge, accessed from all modalities of input (e.g., Caramazza et al., 1982; Jackendoff, 1987; Riddoch & Humphreys, 1987). On the other side of the debate are those who proposed that semantic knowledge is modality-specific—that is, that there are independent semantic stores for different types of information or different modalities of input (e.g. Paivio, 1971; 1978; Shallice, 1987). Thus, for example, Beauvois (1982) and Lhermitte

and Beauvois (1973), have proposed that there are separate semantic stores for visual and verbal information, and perhaps also a separate store for tactile information (Beauvois, Saillant, Meininger, & Lhermitte, 1978), as depicted in Fig. 2. The visual semantic system presumably stores image-like representations of objects and/or provides information as to colour, shape, size, etc. (e.g. an apple is round and red); whereas the verbal semantic system stores information that is best represented in a "verbal" form (e.g. apples grow in temperate regions) (see Shallice, 1987, for further discussion).

Elsewhere (Caramazza et al., 1990), we have argued that the multiple semantics hypothesis does not constitute a theoretically coherent claim about the kinds (and format) of information represented in the various semantic systems. In fact, it is our contention that such notions as "visual semantics" and "verbal semantics", as currently used in the neuropsychological literature, are mere labels for observed dissociations of performance—they do not serve to specify in any clear manner the sets of semantic contents, the formats of representations, or the procedures of access to hypothesised representations which are needed to give theoretical content to such notions as "verbal" and "visual semantics". Still, independently of the theoretical coherence (or incoherence) of such claims, there is

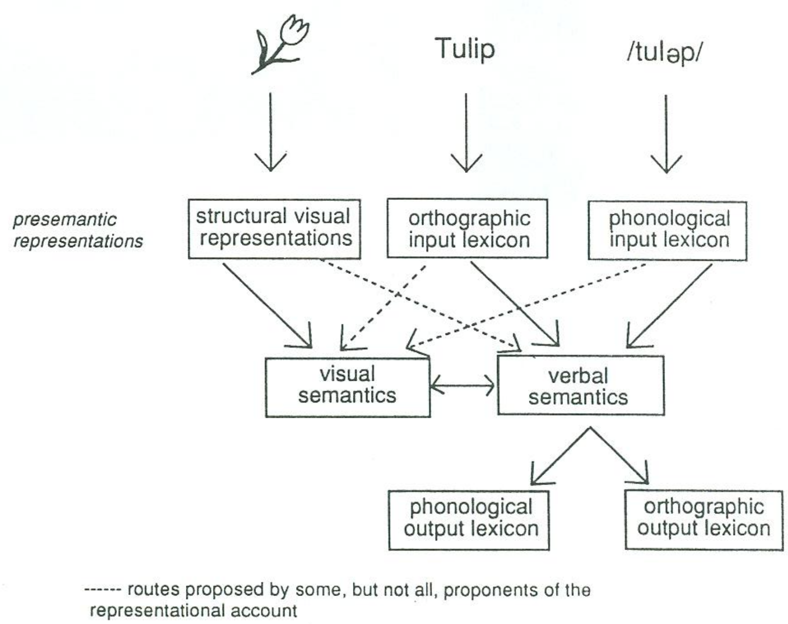

FIG. 2 Multiple semantic systems: the representational account.

the fact that proponents of multiple semantics have pointed to several experimental facts that are supposedly at variance with unitary content semantics hypotheses. It is important, therefore, to consider whether or not the results cited as providing the empirical basis for multiple semantics do in fact undermine unitary content accounts of the semantic system[13].

Processing Assumptions

In examining the relevant evidence, we will be especially concerned with the issue of processing demands in the various tasks that have been used to determine the integrity of semantic processing in different modalities. The claim that reported "dissociations" of performance indicate preserved semantic processing in all modalities but one rests on the assumption that the semantic information that supports performance in each modality is equivalent in terms of processing demands. That is, proponents of this view must assume that the quantity and quality of information needed to accomplish the tasks that have been used to assess "semantics" in nonverbal modalities is equivalent to the quantity and quality of information required to name an object accurately (so-called "verbal semantics"). The former set of information (say, "visual semantics") would presumably differ from "verbal semantics" only in terms of the format (e.g. pictorial versus propositional) or in terms of the sorts of attributes that are represented (e.g. perceptual versus functional). The assumption of equivalence does not appear to be justified with regard to the experimental tasks that have been used to assess the putative systems of meaning.

Consider first the quantity of information required to name an object correctly on a consistent basis: knowledge of all features that differentiate the object from other objects with different names must be obtained. Anything less than this set of features would give rise, at least occasionally, to semantic errors, of the type made by KE and many of the patients reported as cases of "modality-specific aphasias". On the other hand, although we do not pretend to have a reasonably articulated hypothesis of

[13]It is also worth noting that the results we have reported disallow two formulations of the modality-specific semantics hypothesis: (1) There are separate semantic systems, each accessible from a different modality of input, and all with direct access to the output lexicons (the "input account" described in Riddoch et al., 1988 and in Caramazza et al., in press); and (2) There are separate semantic systems for different types of sensory qualities, each accessible from all modalities of input (Fig. 2, dotted lines). The first account could not explain KE's equivalent impairment in naming visually and tactually presented objects and in reading and writing words; and the second could not explain impaired performance on word/picture verification (because the "visual semantic representation" accessed by a word and the "visual semantic" representation access by a picture of a different item would support identification of mismatches, since the referents of foils were visually different from referents of targets on every trial).

the sorts of information that are required to perform successfully tasks such as miming, forced-choice matching, and categorising, we can imagine that these tasks could be performed on the basis of a subset of the features that differentiate the object from similar objects with different names. For example, it seems likely that one could make certain associative judgments, such as matching a pencil to a sheet of paper rather than to a knife (a task performed well by the "optic aphasic" patient described by Coslett & Saffran, in press) by retrieving information that both objects are used in writing or drawing. On the other hand, if only this information were available during attempts to name the objects, either the pencil or paper might be misnamed as the other. Thus, a deficit that impairs access from one modality to some of the distinguishing features of the semantic representation of an item would give rise to an apparent dissociation—proficient naming in one modality versus impaired naming but proficient associative judgments in the damaged modality. Discrepancies between the degree of information needed for naming and for other experimental tasks (e.g., miming) would yield similar, uninterpretable differences between these tasks (see Rapp & Caramazza, 1989, for a similar analysis).

A Modality-neutral Account of Patients' Performance

Having laid the groundwork for our arguments, we now consider the extent to which a particular instantiation of the class of modality-independent, unitary content semantics theories—the Organised Unitary Content Hypothesis (O.U.C.H.) (Caramazza et al., 1990)—can account for the neuropsychological data that have been presented in favour of modality-specific semantics. We begin with a discussion of our own case, KE.

We will assume that a modality-independent semantic representation consists of a set of abstract features or predicates that represent the functional, perceptual, and abstract properties that jointly define the extension and intention of a term (Caramazza et al., 1982). Further, we assume that the semantic identification of an object presented in a particular modality of input requires at the very least: (1) the "construction" of a structural description of the object (in the visual modality, the 3-D level representation proposed by Marr, 1976); and (2) access to a semantic representation that contains an interpreted description of the object and its parts (e.g. a chair has a seat and a backrest . . .) as well as other information about its function (e.g. a chair is a seat for one, it is moveable . . .) and relations to other concepts (e.g. a chair is an artifact, it is a member of the category, FURNITURE, and so forth).

Within this framework, the types of errors made by KE could be explained as being the consequence of damage at the level of the semantic system, resulting in a form of processing that is carried out with impoverished semantic representations[14], such that some functional/perceptual predicates for distinguishing among related items are not computed normally. To illustrate, activation of an incomplete semantic representation for "chair" could specify some predicates common to furniture objects (e.g. that it is moveable, rigid, its canonical location and function), without specifying the functional/perceptual features necessary to distinguish among types of furniture. Thus, the partial representation computed in response to a picture of a chair would fail to distinguish among "stool", "chair", "sofa", "table", "bed", etc., and address corresponding phonological (or orthographic) representations in the output lexicons. Equivalent error types would be predicted in dictation and reading tasks, since the auditory or printed word would compute similar (impaired) representations. Therefore, KE's variable semantic co-ordinate errors (as well as inconsistent correct responses) and his category-specific pattern of semantic errors in all modalities could be explained as resulting from damage to a modality-independent semantic system.

The hypothesis that in lexical tasks semantic errors (or, more precisely, at least some of them) result from the inability to compute a full semantic representation for a term has been used to account for other aspects of patients' naming performance. Howard and Orchard-Lisle (1984) proposed that semantic errors in comprehension and cued naming (production of semantic paraphasias when given an incorrect phonemic cue, and correct naming when given a correct phonemic cue) by a patient, JCU, could be explained by assuming that she relied on partial semantic information in name retrieval and comprehension tasks. However, because JCU could nonetheless match associated objects, such as a thimble to a needle rather than to a cotton reel, Butterworth, Howard, and McLoughlin (1984, p. 423) argued that "an explanation of [her performance] in terms of a modality-independent semantic or conceptual deficit is not possible". But, if we assume that JCU had only partial semantic information available about the objects, say, only that needles and thimbles are used for sewing, she might well produce the reported responses—i.e. accept the name "needle" for a thimble, produce the name "needle" in response to a picture of a thimble presented with the cue /n/, *and* match the thimble to a needle as opposed to a cotton reel. Because correct performance on the picture association task does not require the degree of semantic information that is required for rejection of semantically related names, correct performance on the former and errors on the latter task can both occur as a result of access to incomplete, modality-independent semantic information. Furthermore, the incomplete semantic information (e.g. USED FOR SEWING) available in response to the thimble would serve to activate output representations for "thimble", "thread", "needle", and so on. In this case, a correct phonemic cue would provide additional activation of the correct name, and the incorrect cue /n/ would provide additional activation of "needle"—resulting in precisely the observed pattern of responses.

[14]Although our hypothesis is presented in terms of an impaired representation, it might equally well be presented as impaired access to the complete representation, i.e. access to only a portion of the defining features.

Like JCU, KE occasionally demonstrated better performance in non-lexical tasks (such as miming in response to pictures) than in lexical tasks with the same items. For example, KE produced an accurate gesture (spearing) for a picture of a fork, but labelled a pictured fork as "spoon" and read the word *fork* as "spoon". This discrepancy in performance with words and objects can easily be explained without having to postulate modality-specific semantic representations or subsystems. The explanation we will offer is based on the assumption that words and objects differ in the opportunities they provide for accessing semantic information—the principle of privileged accessibility (see Caramazza et al., 1990, for detailed discussion). The motivation for this assumption stems from the fact that whereas the relation between the orthographic or phonological structure of a word and the semantic predicates that comprise its meaning is arbitrary, the relationship between the perceptual attributes of an object and the corresponding perceptual and functional semantic predicates is far from arbitrary (e.g. the relationship between the perceptual structure of the back of a chair and its interpretation as a backrest is not arbitrary). This asymmetry in the relation between the stimulus structure of words and objects with respect to their semantic representation has important consequences for the relative accessibility of semantic information from objects and words in conditions of brain damage. That is, since objects or pictures provide a much richer source of information about their perceptual attributes than do words, these perceptual features may be interpreted semantically even if the picture fails to address a complete semantic representation.

If a word, on the other hand, fails to address a complete semantic representation, there are no additional cues available to provide meaning. Consider as an example the case where the semantic representation of FORK is underspecified (such that it is equally compatible with "fork" and "spoon", say). A picture of a fork contains perceptual features that may be semantically interpreted—for example, the tines might be perceived and the knowledge that tines are for spearing objects might be accessed from a semantic representation corresponding to tines[15]. If presented with the auditory or written word "fork", this additional information would not be available from the orthographic or phonological string. Thus, it is conceivable that KE was able to use objects and gesture the function of objects correctly by recovering (1) partial semantic information (e.g. sufficient predicates to determine the superordinate category) which would allow broad judgments or gross actions—available from words as well as from visual stimuli; and (2) intact interpretation of perceptual features often available from pictures, but not from words, which would support more distinctive gestures. Interpretation of perceptual features would not necessarily be sufficient for accurate naming of pictures if the semantic representation of the item (or access to it) were impaired. Note, finally, that this hypothesis predicts that KE should make miming errors when the stimulus is a word. As reported here, this pattern is precisely what was observed.

There is another aspect of KE's performance which might at first appear problematic for unitary content hypotheses of the semantic system: KE's seemingly paradoxical ability to sequence the pictures of animals by size and to colour pictures appropriately despite his poor performance in naming and comprehension tasks with the same objects. Once again, however, these results are not at all incompatible with unitary accounts of semantic representation. There are at least two possible explanations that could be offered for the observed dissociation in performance with objects. One explanation, already discussed, is simply that performance on these tasks requires much less information than naming, so that partial information about objects could be sufficient to support good performance on the sorting tasks. However, the interpretation we want to entertain here is one that appeals to differential accessibility of semantic predicates from perceptual attributes of an object—the principle of privileged accessibility—

[15]Of course, the semantic representation of individual features might also be impaired. However, representation of features that are common to a number of separate concepts (e.g. TINES may be features for distinguishing pitchforks/shovels; forks/spoons; spears/clubs, etc.) might be relatively invulnerable to disruption, by nature of their simplicity or frequency of activation. Also note that some appropriate gestures for a fork would be indistinguishable from gestures for spoons (e.g. scooping, mashing, prodding, or bringing something to the mouth) or knives (e.g. cutting with the side of a fork—an acceptable behaviour in the States, at least!), but such ambiguous gestures would not require additional explanation, because they are perfectly compatible with an underspecified semantic representation. In fact, we noted earlier that the majority of KE's responses were indeed ambiguous. It is only the cases where he produced a gesture that seemed to be specific for a particular item which supposedly require additional considerations in order to be reconciled with unitary content accounts of semantic processing.

combined with the assumption that the links among the semantic predicates that jointly define the meaning of a term are not all equal in strength, but are graded—the principle of privileged relationships (see Caramazza et al., 1990, for discussion). Thus, for example, we could assume that the semantic predicates concerning the colour of an object are more strongly linked to the semantic predicates concerning the shape of the object than to those concerning its characteristic sounds or functions. In light of these considerations, the intepretation we offer turns on the assumption that information about perceptual predicates of objects have a greater chance of being accessed correctly from structural descriptions of objects than from words, and, in turn, this information differentially activates related semantic predicates. For example, perceptually salient features of a tiger, such as a series of white, curved, and pointed projections, might be interpreted as claws or teeth—components that might themselves specify a range of acceptable colours and sizes, and perhaps contribute information regarding the category of animal—even if the complete semantic representation of TIGER (the entire set of predicates) is not available. Consequently, there is a good chance that the patient would perform well on tasks that depend on access to partial semantic information, particularly concerning perceptual attributes depicted in, or accessible from, visual (picture or object) stimuli.

In summary, it is possible to explain all aspects of KE's performance by proposing damage to a single semantic system. More specifically, his pattern of performance is consistent with an impairment that results in the ability to use information that is normally used to distinguish members of the same semantic category (e.g. forks from spoons). Our account of his performance rests on the hypothesis that naming objects from vision entails modality-specific perceptual parsing of the computed structural description, which allows interpretation of individual perceptual features as well as access to the full semantic description associated with the object as a whole—the O.U.C.H. model of semantic processing (see Caramazza et al., 1990).

Having provided a plausible account of the data from our own case, we now attempt to determine if the evidence presented by Shallice (1987; 1988a) and by others in support of modality-specific semantics can be accounted for by the O.U.C.H. model. There are several patterns of performance by brain-damaged subjects that have been offered as evidence against modality-independent semantics: (1) modality-specific semantic memory deficits; (2) modality-specific priming effects; and (3) modality-specific naming impairments. Patients described as presenting modality-specific comprehension impairments have also been reported; however, methodological weaknesses make these cases difficult to interpret[16,17]. We will evaluate each of the remaining sources of evidence in turn. In this discussion we do not attempt to account for all aspects of the patients' performance, but only those features that have been presented as the basis for rejecting the hypothesis of a unitary content semantic system.

Modality-specific Semantic Memory Deficits. Schwartz, Marin, and Saffran (1979) described a patient with progressive dementing disease, WLP, whose gestures for pictures were more accurate than naming or word/picture matching. As in the case of KE, her performance may be accounted for as resulting from damage to a modality-independent seman-

[16]Bub, Black, Hampson, and Kertesz (1988) describe a patient, MP, who appeared to gain more information from picture stimuli than from words. However, many of the differences between modalities may have arisen, at least in part, from the nonverbal instructions provided. For instance, one task designed to evaluate comprehension of pictures versus words entailed choosing the "dangerous" animal from three choices of words or pictures. Since MP's auditory comprehension was severely impaired, task instructions consisted of presenting photographs of wild animals in threatening postures and then presenting illustrations of noncarnivorous, harmless animals in order to "allow her to form a concept of the relevant dimension" (p. 32). MP's judgments about the pictures provided in instructions, which were sufficient for her to make the same judgments about most of the test pictures, may have been restricted to interpretation of certain visual attributes (e.g. claws or fangs). The absence of such visual attributes among words would explain her inferior performance with verbal stimuli. It is difficult to know, however, what aspects of the stimuli supported her above chance performance in selecting the larger animal of a pair of pictures or her adequate ability to judge which objects were made of metal, used by a man, or foreign. The authors proposed that her ability to form concepts such as "foreign" versus Canadian and to make judgments about pictures along such a dichotomy, in the face of "profoundly impaired" comprehension of words, was supported by: (1) intact identification procedures, but loss of core concepts (after Miller & Johnson-Laird, 1976), or (2) a different (and less impaired) level of entry to the semantic system for pictures than for words. Both of these hypotheses assume that the patient fails to obtain a complete semantic description—the same assumption we are making to account for KE's performance. And, although we did not test the same range of tasks as did Bub et al., MP's performance on several tasks (e.g. size judgments, word/picture verification) was very similar to KE's, and might be subject to the same interpretations—i.e. performance on all of the tasks could have been supported by partial semantic information available from both words and pictures. As we have already mentioned, however, MP (also reported in Bub et al., 1985) clearly used some mechanisms for reading aloud that were not available to KE.

[17]Goodglass and Budin (1988) described a patient, Mr. A, who showed relatively adequate comprehension of printed words, but impaired comprehension of auditory words. The auditory deficit was more pronounced in some categories than others. However, no attempt was reported to match stimuli in the affected categories for word length, and 10/11 categories showed impaired performance in both modalities—only "desk implements" (n = 9) and uncategorised objects (n = 14) were responded to correctly on all trials of reading. Mr. A's discrepancies in performance may reflect a peripheral auditory processing problem, more than semantic difficulties, since he was also completely unable to judge rhyming words auditorily or to point to nonwords or words spoken by the examiner. Additionally, Mr. A appears to have a mild semantic deficit, since there were also some errors (3–10% category) in reading.

tic system, as follows: WLP had difficulty with naming and word/picture matching because she failed to compute a full semantic representation for objects and words. Her good performance in the use of objects can be explained by assuming that the partial semantic information she was generally able to compute, along with her unimpaired ability to analyse the perceptual features of an object semantically (e.g. tines for spearing), was sufficient for the task.

Performance by patients with category-specific semantic memory impairments, JBR and SBY (Warrington & Shallice, 1984) can also be explained by assuming damage to modality-neutral semantic representations—particularly of living things. These patients were able to identify pictures of inanimate objects more accurately than they could identify pictures of living things. They showed the same, but less striking, difference when presented with names of the objects. Although these patients were described as having a modality-specific impairment, the differences between modalities could largely be attributable to differences in response requirements in the two modalities. That is, they were asked to *identify superordinate information* in response to words (which they did well), whereas they were asked to *provide the name* in response to pictures (which they did very poorly for living things). When asked to define referents of words or pictures, performance was poor for living things represented in either modality, but more accurate for inanimate objects in response to pictures than in response to words. These patients' performance may be explained by proposing damage to a single semantic system in which only enough information to identify the superordinate category of living things was available, but more information was available for inanimate objects. Visual cues provided by picture stimuli may have augmented partial information about inanimate objects, allowing more complete definitions in the visual modality.

Silveri and Gainotti (1988) report performance of a patient, AL, who, like the "semantic memory" patients reported by Warrington and Shallice, was more impaired in identifying (by naming *or* describing) living things than in identifying inanimate objects, in response to both picture and word stimuli. That is, AL exhibited a comparable category discrepancy in various tasks across modalities. She had the most difficulty identifying animals, and particularly wild animals relative to domestic animals. In addition, Silveri and Gainotti claimed that AL showed poorer performance naming animals to description when the description emphasised perceptual information (1/11 correct) than when the description emphasised verbal information or metaphor (8/14 correct). On the basis of this evidence alone, the authors concluded that AL's errors arose from degradation of "visual semantic" information, in the presence of more intact "verbal semantic" information. However, the discrepancy in accuracy levels of responses to the two sets of descriptions can just as easily be explained by differences between the two sets of animals described (mostly domestic versus mostly wild animals), as by appealing to the difference in the verbal/perceptual character of definitions. In every test of naming or identifying pictures or words AL had less difficulty naming domestic animals than wild animals. Thus, it is not at all surprising that on the naming-to-description task AL was more proficient (58%) in naming a set of 14 animals, 11 (79%) of which were domestic animals (and were described with "verbal" features), than in naming a set of 11 animals, 2 (18%) of which were domestic (and were described with perceptual features). Given that higher accuracy on the former set was predicted by her less impaired performance with domestic, compared to wild, animals, the type of information given in the description may be irrelevant. In fact, naming performance on the task using definitions based on nonvisual attributes (58% correct responses) was no better than her performance on word/picture matching with domestic animal stimuli. Thus, the difference observed in naming in response to the two sets of definitions does not constitute evidence that AL's verbal semantic knowledge is better preserved than her corresponding visual semantic knowledge. Indeed, contrary to the interpretation favoured by Silveri and Gainotti, the results reported for AL provide strong evidence that her errors on all verbal and visual tasks arose from damage to a single semantic component.

Modality-specific Priming (Cueing) Effects. A patient described by Warrington and Shallice (1979), AR, was aided in reading a word (e.g. *pyramid*) considerably more by an auditory-verbal prompt ("Egypt") than by a picture of what the word represented. This result suggested to the authors that information was available to the patient primarily from a verbal semantic store and was, consequently, interpreted as support for modality-specific semantics. However, if both the word *pyramid and* a picture of a pyramid addressed only a subset of AR's semantic representation for these stimuli (e.g. predicates of MASSIVE & ANCIENT & STONE & STRUCTURE—which might equally activate output representations for "Stonehenge", "parthenon", and "Taj Mahal"; or ROYAL TOMBS—which might equally activate output representations for "Taj Mahal", "Westminster Abbey", and "Windsor"), then the additional features of pyramid contributed by the auditory-verbal prompt, "Egypt" would increase the information relevant to selection of the target response more than the picture of a pyramid would. A picture of a pyramid would simply address the same subset of semantic information, adding redundant activation of the target and related output representations. AR's ability to categorise words that he could not read is also consistent with the hypothesis of incomplete computation of semantic representations, as discussed earlier (see also Rapp & Caramazza, 1989)[18].

Modality-specific Aphasias. Perhaps the most convincing modality-specific effects have been reported for patients whose naming is impaired from one modality relative to other modalities—cases of "optic aphasia" (Lhermitte & Beauvois, 1973), "tactile aphasia" (Beauvois et al., 1978), and anomia for environmental sounds (Denes & Semenza, 1975). Optic aphasia, for example, is characterised by impaired naming of stimuli presented in the visual modality, in the face of correct naming of the same items presented in other modalities (e.g. tactile) and intact recognition in all modalities. The logic of the argument in favour of modality-specific semantics is as follows: modality-specific aphasia cannot be attributed to damage to output mechanisms, because naming is intact with other modalities of input, nor can it be attributed to failure to compute a unitary, modality-independent, semantic representation because good recognition of items is demonstrated *even* in the impaired modality. On the basis of this reasoning, the conclusion is reached that modality-specific anomia must be attributed to a disconnection between the verbal semantic system that supports naming and the semantic system accessed from the impaired modality (cf. Beauvois, 1982). The cornerstone of this argument is the demonstration of intact semantic processing in the impaired modality. Therefore, proponents of modality-specific semantics have presented data they take to be the critical evidence of the integrity of semantic processing in the impaired modality.

For example, Denes and Semenza (1975) described the case of PWD, who was impaired in naming environmental sounds (only 4/20 correct), although naming of visual, tactile, and olfactory stimuli was very accurate. PWD was also able to match an environmental sound with a picture of the source of the sound when presented with a four-choice decision task (17/20 correct). This latter performance was taken as evidence of intact semantic processing in the impaired modality. Beauvois et al. (1978) described a patient, RG, who had greater difficulty naming or describing objects presented tactually than he had naming items presented auditorily or visually. Nonetheless, he was able to mime correctly the use of objects

[18]There are aspects of AR's performance that require the postulating of additional impairments—particularly in processing picture stimuli. For example, picture naming was poor regardless of prompts (e.g. the cue "Egypt" for *pyramid*). However, since Shallice (1987) suggested that it is the presence of within-modality priming (with words) and absence of across-modality priming (pictures to words) that presents difficulty for the hypothesis of a single semantic system in lexical processing, we have simply shown that this single finding does not, in fact, present an obstacle for our thesis.

presented tactually. RG's adequate miming with tactile presentation, and errors that were semantically related to the targets, were interpreted as signs of adequate semantic processing in the impaired (tactile) modality. Similarly, patient JF (Lhermitte & Beauvois, 1973), was able to pantomime correctly the use of objects misnamed upon *visual* presentation. JF's naming of pictures and objects presented visually was inferior to his naming of items defined auditorily or presented tactually.

In many of these cases of "modality-specific aphasia" a comparison of performance accuracy across modalities is problematic, as different items were presented in different modalities. Of greater concern is the fact that the bias for asserting that semantic processing is unimpaired in a modality consists of good performance in miming or forced-choice tasks. However, it is our contention that such inferences may be unwarranted. For example, Riddoch and Humphreys (1987) have argued that miming and forced-choice matching can be accomplished on the basis of "presemantic" structural information, in the face of disrupted transmission of modality-specific perceptual information to an amodal semantic system. Consistent with this explanation, they describe a patient, JB, who, like JF (Lhermitte & Beauvois, 1973), showed poorer naming of objects on visual presentation than on tactile presentation. He was also able to perform appropriate mimes for many objects he was unable to name. Riddoch and Humphreys, however, demonstrated that JB was impaired in accessing associative knowledge about objects from vision (e.g. JB was unable to identify the co-ordinately/superordinately related items from a cup, a colander, and a saucer). Thus, in an instance where access to semantics was tested more thoroughly, the patient failed to show adequate semantic interpretation despite being able to perform adequately in a miming task[19,20]. Riddoch and Humphreys attributed their patient's modality-specific naming difficulty to impaired access to a modality-independent semantic system, in the face of intact presemantic, structural representations that allow adequate miming.

[19]However, it was not explained *how* JB accomplished miming without accessing a semantic representation. Riddoch and Humphreys evoke the possibility that learned action routines might be addressed directly from a presemantic representation. We sympathise with Shallice (1988a) in doubting that elaborate gestures could be performed without accessing (semantic) information about the function of the object. Rather, gestures seem to require at least broad sorts of semantic distinctions (e.g. attaining the functional category, such as "food" or "utensils"), perhaps along with interpretation of *some* of the perceptual attributes that would further constrain appropriate actions. But Shallice (1988b, p. 293) also challenges the argument that mimes are more ambiguous than names on the basis that 30% of the naming errors by the tactile aphasic patient, RG, were perseverative. He states, "It is difficult to understand why perseverations did not occur with the mimes if mimes merely provide a less sensitive measure of the same underlying process". However, perseverations in naming *can* be explained by assuming that impaired semantic information fails to provide sufficient activation of the correct entry in the phonological output lexicon, so that the currently most activated representation is produced in its stead. Perseverative mimes might be blocked by additional information from the picture that limits the range of appropriate actions.

[20]Coslett and Saffran (in press) also tested a patient whose naming performance conformed to patterns described as optic aphasia, on various measures of functional similarity, associative judgments, and categorisation. Unlike JB, their patient performed as well as a normal control on these tests. In contrast, another patient who fitted the classic description of optic aphasia, AG reported by Hillis (Note 1), carried out tasks similar to those used by Coslett and Saffran with far poorer accuracy (e.g. 65% correct categorisation of furniture, as chairs/stools/tables, etc., compared to 100% correct by an age-matched control subject). It seems that these sorts of tasks require *some* semantic and/or perceptual information—not necessarily an intact semantic representation—which is available to some "optic aphasic" patients and not to others. Consistent with this hypothesis, AG and most of the optic aphasic patients reported in the literature made co-ordinate semantic errors in naming (e.g. chair → "table"), whereas the patient reported by Coslett and Saffran made only superordinate (e.g. chair → "furniture") errors, visual confusions, and unrelated responses. These differences lead us to conjecture that the various patients have available different sorts of semantic information about objects encountered visually, to constrain their naming (and nonverbal) responses.

The explanation we prefer for the reported dissociations is based on the assumption that miming and forced-choice matching can be accomplished by accessing incomplete semantic knowledge of the stimuli. Thus, imagine a situation where the structural description of an object specific to a given modality (say, the 3-D level description computed from a visually presented object) fails to activate its corresponding (full) semantic representation. In such a case it would not be possible to produce the name of the object nor, indeed, to perform any other task requiring semantic processing, in response to the visual stimulus alone. However, access to the semantic representation from other modality-specific input representations (orthographic or phonological lexical representations or the structural descriptions computed from tactile input) might be preserved. Further imagine that although access to the full semantic representation is impaired in the visual (or other *perceptual*) modality, some of the individual semantic predicates (e.g. pointed, handle, etc.) of an object are directly activated by corresponding perceptual attributes—the assumption of privileged accessibility. In this case, the activated information may be sufficient to support miming or categorisation performance with the object, but insufficient to select its name.

Within this basic framework there are at least two sorts of deficits that might result in the pattern of performance that has been called "modality-specific aphasia". Consider the case of so-called optic aphasia. On one of the two accounts, the observed dissociation may result from a deficit in semantically interpreting *as a whole* the normally computed 3-D structural description (or its equivalent in the tactile and auditory modalities), while sparing the ability to interpret semantically (some or all) *individual* perceptual features. The other account assumes that there is a deficit in actually computing the 3-D structural description of objects, with the consequence that it will not be possible to activate corresponding semantic representations. On this view, if we were to further assume that it is possible to interpret semantically individual perceptual features in the 2½-D sketch (or its equivalent in other sensory modalities) we would then have a situation where some of the perceptual semantic predicates of an object could be activated even though the full semantic representation for an object could not be computed normally. In the case of either type of deficit we have described, only partial semantic information—activated by individual perceptual features—would be computed in the impaired modality. In both cases we assume that the incomplete semantic information that is computed in these circumstances can support certain kinds of appropriate responses, such as gestures indicating an object's function, but not others, such as naming. Thus, the two forms of damage discussed here would both produce the general pattern of dissociation labelled "optic aphasia" (impaired naming but intact miming from visual presentation, along with intact naming from other modalities), but they might result in different patterns of performance with respect to the range of responses that are possible in the impaired modality. Indeed, such variability is found in the literature (see for example Coslett & Saffran, in press, versus Riddoch & Humphreys, 1987).

In conclusion, we have presented a case study in which a pattern of impaired performance can be explained as resulting from selective damage to a single semantic system involved in lexical processing. We have argued that the contrasting levels of performance between verbal and perceptual modalities, in KE and in other relevant cases, might well be explained by differences in the demands of various tasks designed to evaluate "semantic processing". We have concluded by proposing a model of semantic processing—the Organised Unitary Content Hypothesis (Caramazza et al., 1990)—which when appropriately "lesioned" can account for KE's performance as well as the performance patterns of other brain-damaged subjects who had previously been considered as problematic to the unitary semantics hypothesis.

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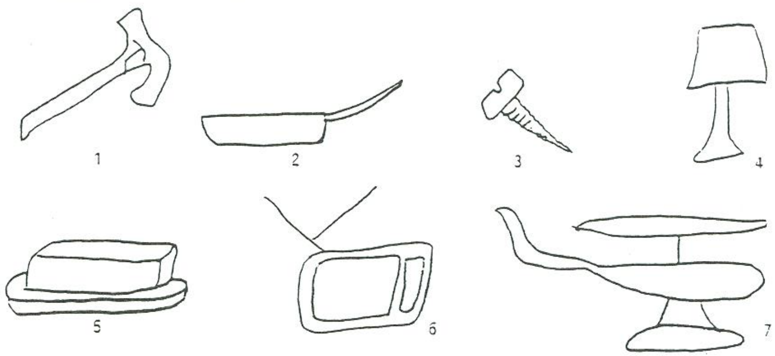
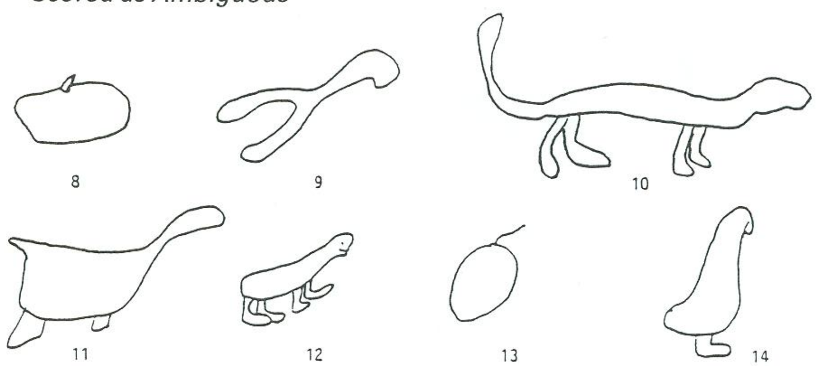
APPENDIX A

Examples of KE's Drawings in Response to Words

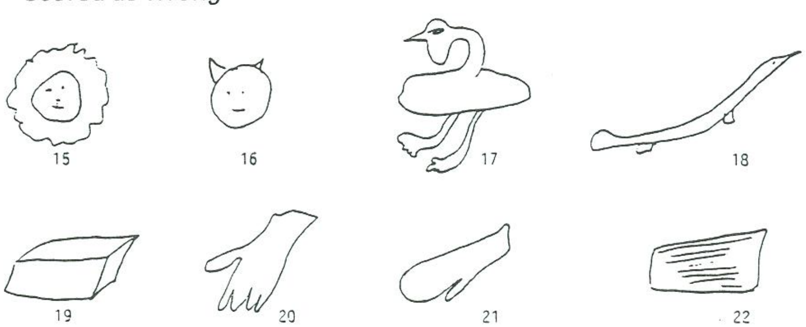
Scored as Correct



Scored as Ambiguous



Scored as Wrong



Key: stimulus words

1. hammer
2. pan
3. screw
4. lamp
5. butter
6. television
7. helicopter
8. orange
9. pliers
10. leopard
11. turkey
12. frog
13. grapes
14. eagle
15. tiger
16. bear
17. penguin
18. frog
19. tape
20. mitten
21. glove
22. spatula

APPENDIX B

Examples of KE's Reponses Across Tasks

List 1a

Stimulus	*Oral Reading*	*Oral Naming*	*Written Naming*	*Dictation*
arm	ear	finger	leg	hand
elbow	foot	leg	leg	leg
stomach	belly	belt	wrist	belt
nose	ears	ear	+	neck
toes	ear	foot	finger	mouth
knuckle	ear	ears	wrist	neckul
lips	no	legs	+	desire
truck	boat	van	bus	+
tractor	trailor	+	trailor	trailor
rocket	jet	jet	jet	ject
helicopter	plane	airplane	tractor	airplane
leopard	tiger	tiger	tiger	tiger
raccoon	rabbit	rabbit	+	rabbit
frog	lizard	turtle	+	turtle
lobster	crabs	shrimp	shrimp	quickly
bean	peas	peas	pea	+
apple	peach	peach	pear	+
pear	peach	peach	+	peach
peach	orange	banana	N/R	lime
sofa	chair	chair	chair	bed
stool	chair	chair	chair	+
shelf	lamp	chair	light	lamp

N/R = no response; + = correct response

List 1b

Stimulus	Oral Reading	Oral Naming	Written Naming	Dictation	Auditory Word/ Picture Matching	Printed Word/ Picture Matching
helicopter	airplane	airplane	jet	motorcycle	airplane	airplane
rocket	airplane	jet	jet	jet	N/R	airplane
truck	jet	airplane	bus	+	tractor	+
wrist	ear	foot	leg	hand	+	leg
nose	toes	ear	+	finger	ear	ear
elbow	leg	foot	finger	tooth	leg	leg
toe	ear	+	+	elbow	finger	finger
ankle	elbow	ear	leg	+	foot	+
finger	tummy	ear	thumb	+	foot	leg
arm	back	foot	leg	elbow	foot	leg
shoulder	finger	ear	ear	+	arm	arm
clam	oysters	crab	lobster	crab	crab	lobster
bean	+	carrots	pea	pea	pea	pea
apricot	apple	tomato	tomato	apple	cherry	cherry
dolphin	+	whale	whale	whale	N/R	N/R
shark	N/R	tiger	whale	whale	tiger	+
leopard	lion	tiger	tiger	+	tiger	tiger
sock	+	gloves	mittens	mitten	mitten	mitten
jacket	+	belt	sweater	sweater	pants	pants
bureau	couch	desk	door	desk	chair	desk
drawer	door	chair	desk	bureau	desk	table
bed	couch	couch	+	+	couch	couch

N/R = no response; + = correct response

List 2

INPUT:	Tactile		Picture		Printed Word		Auditory Word	
TASK:	Oral Naming	Written Naming	Oral Naming	Written Naming	Reading	Object Matching	Dictation	Object Matching
Stimulus								
sneaker	shoe	sock	belt	sock	shoe	slipper	shoe	sock
shirt	sock	+	shoe	jacket	sock	+	+	sock
glove	sock	mitten	scarf	+	baseball	mitten	+	mitten
tie	belt	+	belt	belt	towel	+	+	belt
sock	+	shoe	belt	belt	+	+	tie	tie
apple	orange	oranges	+	orange	orange	orange	+	lemon
lemon	+	orange	orange	+	orange	+	+	–
spatula	sponge	sponge	sponge	sponge	+	+	pan	pan
pot	bowl	pan	+	+	+	bowl	pots	–
fork	knife	knife	+	+	knife	knife	knife	knife
sponge	towel	spoon	wipe	wash	wash	+	N/R	towel
brush	+	comb	comb	brusher	+	comb	comb	comb
hammer	pliers	+	pliers	+	+	+	+	pliers
screw	plug	+	+	nail	hammer	nail	cent	hammer
nail	hammer	+	screw	nut	pliers	+	+	–
pliers	knife	N/R	+	jack	+	+	plumber	–
stapler	paperclip	paperclip	paperclip	paper	paper	paperclip	scissors	paperclip
tape	paper	paper	paper	clip	paper	paperclip	pencil	–

N/R = no response; + = correct response