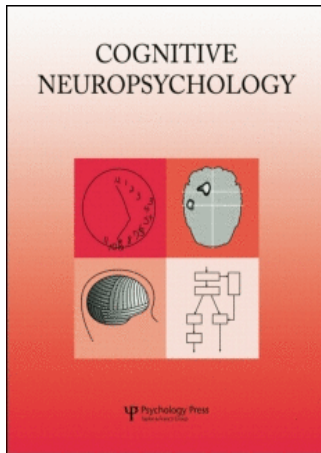


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Publisher: Psychology Press
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Cognitive Neuropsychology

Publication details, including instructions for authors and subscription information:
<http://www.informaworld.com/smpp/title~content=t713659042>

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Online Publication Date: 01 July 2000

To cite this Article: Ralph, Matthew A. Lambon and Howard, David (2000) 'GOGI APHASIA OR SEMANTIC DEMENTIA? SIMULATING AND ASSESSING POOR VERBAL COMPREHENSION IN A CASE OF PROGRESSIVE FLUENT APHASIA', Cognitive Neuropsychology, 17:5, 437 - 465

To link to this article: DOI: 10.1080/026432900410784

URL: <http://dx.doi.org/10.1080/026432900410784>

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GOGI APHASIA OR SEMANTIC DEMENTIA? SIMULATING AND ASSESSING POOR VERBAL COMPREHENSION IN A CASE OF PROGRESSIVE FLUENT APHASIA

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Many patients with progressive fluent aphasia present with poor verbal comprehension and profound word-finding difficulties in the context of much better picture comprehension and object use. The Japanese term *Gogi* (literally “word-meaning”) *aphasia* matches this behavioural pattern. The alternative label of *semantic dementia* is most often used for these patients and this term emphasises a generalised degradation of conceptual knowledge that encompasses both verbal and nonverbal comprehension. The study presented here investigates whether progressive fluent aphasia has a functional impairment limited to the verbal domain (*Gogi* aphasia) or more widespread involvement of all conceptual knowledge (*semantic dementia*).

We report data collected from a patient with progressive fluent aphasia, IW, who presented with profound word-finding difficulties and relatively poor word comprehension. The predictions of three theoretical interpretations of this pattern are investigated in a series of experimental tasks. We argue that IW’s poor verbal comprehension and anomia cannot easily be explained as an impairment to either a semantic lexicon or a modality-specific verbal semantic system. Instead we favour an explanation in terms of a single impairment to a unitary semantic system within a framework that emphasises the underlying differences in the mapping between surface form and meaning, for words and pictures. We demonstrate how IW’s pattern of data can be replicated in an implemented connectionist network that includes a systematic mapping for pictures but an arbitrary relationship for words. We conclude that although *Gogi* aphasia may be an accurate clinical description of the most striking features observed in progressive fluent aphasia, the disorder is primarily a progressive loss of conceptual knowledge—it is *semantic dementia*.

INTRODUCTION

Progressive fluent aphasia is a disorder associated with progressive circumscribed atrophy of the

inferior and lateral aspects of the temporal neocortex. The atrophy typically involves the left side (Hodges, Garrard, & Patterson, 1998; Hodges, Patterson, Oxbury, & Funnell, 1992) although

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We are indebted to IW for her continued patience and support of our research, and to Dr Richard Wise for the neuroimaging results. MALR was supported by a grant from the National Institutes of Health (to J.L. McClelland and K. Patterson). We would like to thank Eleanor Saffran and two anonymous reviews for their insightful comments on a previous version of this paper.

recent voxel-based morphometry suggests that there is always bilateral involvement (Mummery, Patterson, Wise, Price, & Hodges, 1999). The progressive loss of temporal structures is associated with an increasing comprehension deficit and profound anomia. Despite sometimes severe semantic impairment, the patients perform well on tests of nonverbal reasoning, perceptual and spatial skills, have good single-word phonology, syntax and day-to-day (episodic) memory (Hodges et al., 1992; Snowden, Goulding, & Neary, 1989).

In most studies of progressive fluent aphasia researchers have argued that the patients' poor comprehension as well as their severe anomia with concurrent semantic paraphasias point towards a progressive impairment of the underlying conceptual knowledge—and thus the term *semantic dementia* has been adopted (Hodges et al., 1992; Snowden et al., 1989). Other studies have noted that, in these patients, verbal comprehension and production can be affected to a greater degree than comprehension of pictures or objects (e.g., Lauro-Grotto, Piccini, & Shallice, 1997; McCarthy & Warrington, 1988). The difference between verbal and nonverbal abilities is such that in Japan, since 1943, progressive fluent aphasia has been typically referred to as *Gogi*, or “word-meaning,” *aphasia* (Imura, 1943; for more details on these Japanese patients, see Jibiki & Yamaguchi, 1993; Nakagawa et al., 1993; Sasanuma & Monoi, 1975; Tanabe et al., 1996). Indeed Imura, Nogami, and Asakawa (1971, p. 78) stated, “its [*Gogi aphasia*] main symptom is the loss of the *word sense*.” A good example of these patients' poor verbal comprehension was highlighted by Tanabe et al. (1996, p.142); they noted the comments of a patient's spouse who said, “Recently, my husband is unable to comprehend even the meaning of the very popular concrete words such as ‘mirror’ and ‘towel.’ However, he towels his face and looks at himself in the mirror every morning.”

The striking dissociation between apparently intact use of everyday objects and the lack of comprehension of their associated names noted in cases of *Gogi aphasia* has been observed in other patients with progressive fluent aphasia (Buxbaum, Schwartz, & Carew, 1997; Lauro-Grotto et al.,

1997). Lauro-Grotto et al. (1997, p.605) note that when patient RM was “asked to show how to cook ‘spaghetti’, she simply stared at the experimenters, but when she was presented with the actual spaghetti she rapidly collected what was needed and gestured an extremely faithful and detailed account of the cooking procedure”. Lauro-Grotto et al. formally analysed the use and preparation of various foodstuffs by patient RM, and compared it to her ability to identify the same ingredients and implements from their names (a word-to-object matching test). RM's cooking was rated to be “good” or “perfect” for 17/24 (71%) of the different foods, and 48/56 (84%) of the individual ingredients and implements were correctly used. RM's ability to match the correct name to each of these items was significantly worse: 30/56 (53%) and 35/56 (62%) on the two repeated administrations of the test.

How many semantic systems are there?

Lauro-Grotto et al. (1997) argued that the dissociation between verbal comprehension and object use supports a multi-modal semantics position. This theory suggests that conceptual knowledge is stored separately for different input modalities (McCarthy & Warrington, 1986, 1988; Shallice, 1988, 1993; Warrington & McCarthy, 1994). Specifically a major division has been proposed between visual and verbal semantic systems. According to this view it should be possible to identify patients who form a double dissociation between picture and verbal comprehension. Thus, the various patients who demonstrate relatively poor comprehension of words, the individuals with *Gogi aphasia*, form one half of the double dissociation (e.g., Lauro-Grotto et al., 1997; McCarthy & Warrington, 1988). Relatively poor comprehension of pictures but not words has been reported for two patients and is generally cited as evidence for the opposite dissociation (impaired visual but intact verbal semantics: McCarthy & Warrington, 1986; Warrington & McCarthy, 1994). It is entirely possible, however, that the performance of these two patients does not reflect an impairment to a semantic system dedicated to visual knowledge but is the consequence of a presemantic, visual processing deficit (Lambon

Ralph, Graham, Patterson, & Hodges, 1999b; Rapp, Hillis, & Caramazza, 1993).

We shall consider two alternative explanations of Gogi aphasia, or impaired verbal comprehension that posit a single, unitary semantic system. The first assumes that semantic and verbal representations (either written or spoken) communicate via an intermediary store of abstract word forms—a semantic lexicon (Butterworth, 1989; Butterworth, Howard, & McLoughlin, 1984; Nickels & Howard, in press). In this framework, spoken and written words access the appropriate abstract word form which can retrieve, in turn, the corresponding meaning from the conceptual system. Pictures, in contrast, gain direct access to the semantic system. For naming and speech production, however, the semantic representation has to be converted into its corresponding spoken or written form via the appropriate unit within the semantic lexicon. Thus two of the key presenting symptoms of Gogi aphasia, anomia and selective verbal comprehension impairment, could arise from the loss of entries (or access to the entries) in the semantic lexicon such that the patients are unable to translate between conceptual knowledge and verbal representations. In contrast, comprehension of pictures and objects should be unaffected because these stimuli retrieve their meaning via direct access to the conceptual system.

Both the multi-modal semantics and semantic lexicon hypotheses predict that it should be possible to find evidence for a *classical* dissociation between verbal and object comprehension. However, the dissociation is rarely, if ever, a classical one. Graham, Becker, Patterson, and Hodges (1997) reported analyses of the definitions given by a patient with progressive fluent aphasia to a set of concepts presented either as pictures or words. Although the patient did produce better definitions in response to picture stimuli, the information provided was not complete. When comprehension was assessed in other object-based tasks such as the Pyramids and Palm Trees test (Howard & Patterson, 1992), the patient's performance was not entirely normal either. Other patients with impaired verbal comprehension have been found to have deficits in picture comprehension too when this has been

assessed in some detail. For example, patient RM (Lauro-Grotto et al., 1997) performed at chance when required to sort pictures at a subordinate level and was extremely impaired on both the picture and word versions of the Pyramids and Palm Trees test. Although she exhibited a large dissociation between demonstrating the appropriate cooking procedure for the real item and its name, she provided little or no information for a number of the real foodstuffs including two that, presumably, were pre-morbidly familiar to this Italian subject (*aubergine* and *gnocchi*).

Systematic and arbitrary routes to a unitary semantic system: Theory and model

Is there any evidence that positively favours a unitary semantic system? In a functional imaging study with intact subjects, Vandenberghe, Price, Wise, Josephs, and Frackowiak (1996) identified a large semantic network that extended from the left superior occipital gyrus through the middle and inferior temporal cortex to the inferior frontal gyrus. A conjunction analysis revealed that regional cerebral blood flow (rCBF) increased in this area for both word and picture comprehension tasks. Hodges et al. (1996) and Lambon Ralph, Patterson, and Hodges (1997) found a clear relationship between semantic attributes given in definitions by patients with dementia of Alzheimer's type (DAT) to picture names and their performance on the same items when presented for naming to confrontation. If knowledge for pictures and words is stored separately there is no reason to expect any association across these two tasks. In another study of the semantic impairment observed in a series of DAT patients, Chertkow, Bub, and Caplan (1992) found a strong association between performance on probe questions whether presented with the target picture or the corresponding name. A recent study of data collected from nine patients with progressive fluent aphasia identified significant associations between word and picture definitions, and between picture naming and word definitions—again indicating a single amodal store for words and pictures (Lambon Ralph et al., 1999b).

Our brief overview of the literature on this topic has revealed an apparently contradictory pattern. On the one hand, the item-by-item associations identified in the studies noted above together with the common neural system revealed in Vandenberghe et al.'s functional imaging study favour the unitary semantic position. On the other hand, the dissociations between picture and verbal comprehension seem to point towards a multimodal viewpoint. A number of authors have argued that the case for a double dissociation between verbal and nonverbal systems is not complete (Lambon Ralph et al., 1999b; Rapp et al., 1993). As noted earlier, the only two cases with relatively spared verbal comprehension also had concurrent visual perceptual deficits (McCarthy & Warrington, 1986; Warrington & McCarthy, 1994). So if we set these cases aside we have good evidence for both item-specific associations between word and picture comprehension, and between word comprehension and picture naming, plus a number of patients with relatively poor verbal comprehension (those that could be described as Gogi aphasics).

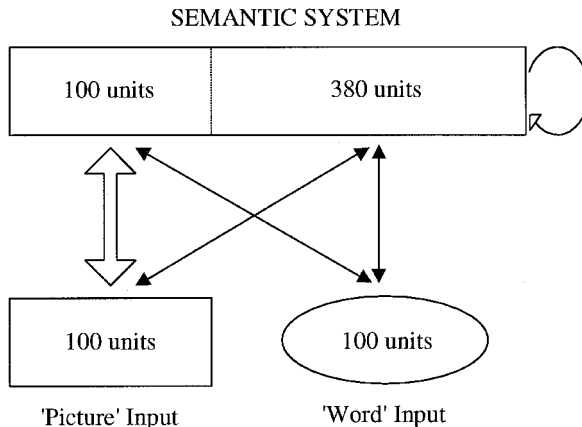
This pattern of results would be readily explained if we assume that the patients do, in fact, have a deficit within a unitary semantic system giving rise to the item-by-item associations, and that relatively poor verbal comprehension arises from the underlying differences in the translation to meaning from pictures or words. The nature of the mapping between surface form and conceptual knowledge for each modality is different: Words, unlike objects, have an arbitrary relationship with meaning. Morton (1985, p. 223) noted that "if we recognise part of an object we can often say a great deal about what the object is" and invoked Gibson's (1979) notion of *affordance* to refer to those properties of the whole object that can be determined without recognising what the object is. Affordance is similar in many ways to the processing assumptions adopted by Caramazza and colleagues (Caramazza, Hillis, Rapp, & Romani, 1990; Hillis, Rapp, & Caramazza, 1995). They have suggested that objects, but not words, allow direct access to meaning (the *assumption of privileged access*) and that, because the relationship between form and function is not arbitrary, knowledge about the

structural aspects of an object will be closely linked to the semantic properties that specify function (the *assumption of privileged relationships*). When these two assumptions are taken together they imply that not only structural but also functional aspects of a concept should be more readily accessed from the object than from its name.

We summarise below the results collected from a connectionist simulation. Although the network was relatively simple, it possessed the key characteristics noted earlier: "Semantic" concepts were represented in a distributed fashion across one set of units (i.e., a unitary semantic system); "word" representations were arranged so that they had an arbitrary relationship between surface form and the conceptual representation whereas the "picture" input was based upon a proportion of the semantic pattern, resulting in a systematic mapping.

Architecture, patterns, training, and testing

The architecture of the model is shown in Figure 1. "Picture" and "word" input layers (100 units each) were fully interconnected to 480 "semantic units" (but not to each other). Fifty semantic patterns were created in the following way: 5 "prototype" patterns were created (randomly assigned +1 or -1 values to each of the 480 units). Nine other "category" exemplars were created by a small random perturbation of each prototype pattern (the probability of switching each bit of the prototype pattern = .025). Input "word" representations were 50 random patterns (randomly assigned +1 or -1 values to each of the 100 units). Input "picture" patterns were created to have a clear relationship to a fraction of the full semantic representation. For each of the 50 concepts, the semantic pattern for the first 100 units was copied. The resultant input "picture" pattern was subjected to a moderate random perturbation (probability of changing the value of each bit = .125), so that it was not an exact copy of the original semantic portion. The model was trained in exactly the same way as the Farah and McClelland simulation (1991) except that no weight decay was applied. Specifically each "picture" or "word" input pattern was presented to the model and the network was allowed to settle for 10 cycles. The weights on the connections between the input and semantic



Note: The arrows denote how the “input” and “semantic” units were connected (full interconnectivity between “picture” and “semantic”, and “word” and “semantic” units, but no connectivity between “picture” and “word” units). The thick arrow between “picture” input and the first 100 of the 480 “semantic” units represents the greater systematicity of the mapping between these representations.

Figure 1. A simple connectionist simulation of word and picture comprehension.

units were adjusted by the delta rule so that the correct semantic pattern was produced from either “word” or “picture” input. Training was continued until learning asymptoted at 300 epochs.

After training was completed, the model was subjected to simulated semantic damage (random proportions of the semantic units were clamped to zero—each level of damage was simulated five times and the results averaged). The pattern of activation produced was considered to be “correct” if the best match between the observed pattern of activation and all 50 possible patterns was the target pattern. If the best match was not the target pattern but one of the other 9 patterns from the same “category”, the error was classified as “semantic”.

Results

Figure 2 shows the effects of different amounts of damage to the semantic system. A number of observations are worthy of note. First, with small amounts of semantic damage there was little or no difference between word and picture comprehension. As the level of damage was increased a considerable difference in comprehension accuracy emerged, favouring picture over word input. Sec-

ond, comprehension errors in response to picture input were typically semantic errors (settling on a different but “semantically” related pattern). For example, when 75% of the semantic units were lesioned, all comprehension errors to picture input were semantic but only 32% were to word input. This provides one explanation for the observation that patients with poor verbal comprehension are often able to give some appropriate information about a picture (i.e., information generally characteristic of exemplars from the correct semantic category) even though it is rarely, if ever, a complete description (Graham et al., 1997; Lambon Ralph et al., 1999b). Finally, we noted earlier that information afforded by pictures may extend beyond the structural features present in the input, and the performance of the network also supports this point. For example, if the normalised dot product is used as a measure of the quality of the conceptual knowledge (Farah & McClelland, 1991), then the available semantic information is greater from “picture” input than from “word” input both for the first 100 semantic units whose activation is closely related to the picture input (with 75% damage—mean normalised dot product for the “correct” trials only: pictures = 0.19, words = 0.12: $t_{(359)} = 19.1, p < .001$)

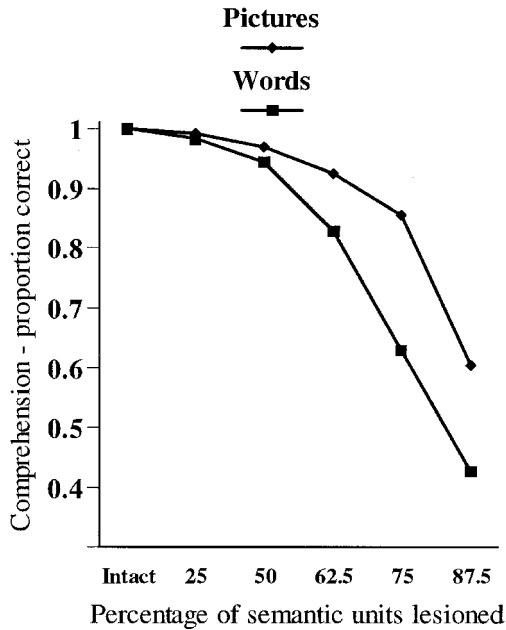


Figure 2. *The effect of lesioning semantic units on word and picture comprehension.*

but also for the remaining semantic units whose activation is not directly related to the picture input (mean normalised dot product for the “correct” trials only: pictures = 0.17, words = 0.10: $t_{(359)} = 24.6, p < .001$). This suggests that the benefit from information present in the picture input applies not only to the directly corresponding conceptual knowledge but in turn propagates to the remaining semantic information (for other demonstrations of the interaction between portions of the semantic representation, e.g., critical mass, see Farah & McClelland, 1991).

We note in passing that the effect of different degrees of systematicity between surface form and conceptual knowledge is not limited to comprehension. The impact of the arbitrary relationship between words and semantics is likely to be particularly pronounced for output—i.e., a mild semantic impairment will lead to a considerable degree of anomia (Lambon Ralph, Cipolotti, & Patterson, 1999a; Lambon Ralph, Sage, & Roberts, 2000). It is possible, therefore, that the two key symptoms of Gogi aphasia—relatively poor verbal comprehension and profound anomia—can be explained by

the nature of the mapping between semantics and word forms, and need not rely on positing either a division within the semantic system itself or an impairment to an amodal semantic lexicon required for translation between the verbal and conceptual domains.

We report data collected from a patient with progressive fluent aphasia who presented with a profound anomia and a marked difference between her poor understanding of spoken words and apparently excellent comprehension of the corresponding objects, i.e., Gogi aphasia. Our experimental investigations attempted to test whether her poor verbal comprehension arose from an impairment in the verbal semantic system, a lexical deficit or the arbitrary mapping between words and their meaning.

CASE REPORT

IW, a left-handed female, was born in 1941. She had been employed in a variety of retail companies including managing a successful florists in London.

IW presented in 1994 after a year or two of "poor memory". Medical examination at that time noted considerable word-finding difficulties for both common objects and people's names. An MRI scan revealed significant localised atrophy of the left temporal lobe. Speech therapy assessment confirmed IW's expressive dysphasia but also noted an auditory comprehension deficit together with a degree of surface dyslexia and dysgraphia.

Our investigation began in 1996. The two obvious presenting symptoms at this time were IW's profound word-finding difficulties in spontaneous speech and her poor comprehension of spoken words even of vocabulary relating to everyday items (e.g., *cup*, *pear*, *bicycle*, etc). An MRI scan showed significant atrophy of the left temporal lobe, most pronounced at the pole, which included significant reduction of the inferior temporal gyrus. IW's right temporal lobe and other cortical structures, including the medial temporal area, appeared to be intact (see Figure 4, Lambon Ralph, Howard, Nightingale, & Ellis, 1998c). A separate but related study of IW can be found elsewhere (Lambon Ralph et al., 1998c). To summarise briefly, we found that like other patients with progressive fluent aphasia, IW had relatively poor knowledge of sensory as opposed to functional/encyclopaedic attributes (e.g., Basso, Capitani, & Laiacina, 1988; Breedin, Saffran, & Coslett, 1994; Lambon Ralph et al., 1999b; Moss, Tyler, Hodges, & Patterson, 1995; Sirigu, Duhamel, & Poncet, 1991; Srinivas, Breedin, Coslett, & Saffran, 1997; Tyler & Moss, 1997) but IW's poor sensory knowledge did not lead to a category-specific deficit for living things as predicted by a number of theories (Farah & McClelland, 1991; Warrington & Shallice, 1984)—in fact once the effect of familiarity and other psycholinguistic variables was partialled out IW demonstrated a small but significant effect that favoured living things.

IW's results across a variety of general neuropsychological assessments and tests of visual and spatial processing are shown in Table 1, split into

the data collected between July 1996 and April 1997 (the time period during which the experimental tasks were conducted—see following) and the assessments repeated in October 1997. IW's verbal IQ was considerably lower than her performance IQ, which was commensurate with her scores on Raven's Coloured Progressive Matrices (Raven, 1962). Her ability to recall autobiographical incidents for all three time periods was as good as control subjects but she was outside the range when required to remember personal semantic information¹ for the time periods included in the Autobiographical Memory Inventory (Kopelman, Wilson, & Baddeley, 1989). Her profound anomia was particularly evident in both letter and category fluency tasks. Her recognition of the unfamiliar faces from the Recognition Memory Test was as good as control subjects but her performance for words was impaired. Although not disorientated in time or place she performed poorly on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) because of her expressive and receptive language deficits.

IW had preserved object recognition and spatial skills. IW performed as well as a control subjects on the object decision task from the Birmingham Object Recognition Battery (BORB: Riddoch & Humphreys, 1992). IW's scores on all the subtests from the Visual Object and Space Perception battery (VOSP: Warrington & James, 1991) were above the cutoff values for her age, including her ability to provide uniquely identifying information for the silhouette pictures (we shall return to this observation later). IW produced a perfect immediate copy of the Rey figure (Osterrieth, 1944) and her delayed copy was as good as control subjects.

Table 2 shows IW's performance on a number of specific language assessments. IW performed extremely poorly on the spoken and written versions of the lexical decision test taken from the ADA battery (Franklin, Turner, & Ellis, 1992). Like most patients with progressive fluent aphasia IW was a surface dyslexic—she was much less

¹Note, however, that the testing of personal semantic memory requires recall of specific names, addresses, etc, which is likely to be specifically impaired by word retrieval. Recall of autobiographical events, by contrast, only requires description. With these items difficulty in word retrieval can be compensated for by circumlocution.

Table 1. *General neuropsychology and assessment of visual-spatial processing*

	<i>Condition</i>	<i>No. of Items</i>	<i>July 96– April 97</i>	<i>Oct 97</i>	<i>Control Data</i>
<i>General neuropsychology</i>					
WAIS-R	Verbal		64		
	Performance		98		
Raven's Coloured Progressive Matrices		36	29	29	50th %ile
<i>Autobiographical Memory Inventory</i>					
<i>Personal semantic</i>	Childhood	21	13.5		16–21
	Early adult	21	15		17–21
	Recent life	21	16		19–21
<i>Autobiographical incidents</i>	Childhood	9	7		6–9
	Early adult	9	8		7–9
	Recent life	9	9		7–9
Fluency	Letter (F,A,S)		16	9	44.6 (<i>SD</i> 10.2)
	Category (8)		27	16	113.7 (<i>SD</i> 19.4)
Warrington Recognition Memory Test	Words	50	35		5th %ile
	Pictures	50	43		58th %ile
Mini-Mental State Examination		30	22		Cutoff >24
<i>Visual and spatial processing</i>					
BORB object decision		128	121	122	114.7 (<i>SD</i> 5.7)
<i>VOSP</i>					
Screen		20	20	20	Cutoff >15
Incomplete letters		20	20	20	Cutoff >16
Silhouettes		30	17	20	Cutoff >15
Object decision		20	17	19	Cutoff >14
Progressive silhouettes			10	14	Cutoff <15
Dot counting		10	10	10	Cutoff >8
Position discrimination		20	20	20	Cutoff >18
Number location		10	10	10	Cutoff >7
Cube analysis		20	9	9	Cutoff >6
Rey figure copy	Immediate	36	36		
	Delayed	36	16		15.2 (<i>SD</i> 7.4)

accurate when reading words with exceptional spelling-to-sound correspondences from both the Psycholinguistic Assessments of Language Processing in Aphasia Regularity List (PALPA; Kay, Lesser, & Coltheart, 1992) and the Surface List (Patterson & Hodges, 1992), and only managed to read three words correctly from the National Adult Reading Test (NART: Nelson, 1982). Although IW's speech was syntactically correct she demonstrated a mild syntactical comprehension impair-

ment when assessed formally on the Test for Reception of Grammar (TROG: Bishop, 1989), although both scores were within the range collected from other patients with progressive fluent aphasia (e.g., see Table 1: Lambon Ralph, Graham, Ellis, & Hodges, 1998b). Despite her other language impairments, IW was able to repeat words and nonwords as well as young normal controls (Franklin et al., 1992). IW's forward digit span was four.

Table 2. *Assessment of language performance*

	<i>Condition</i>	<i>No. of Items</i>	<i>April 95– Sept 95</i>	<i>July 86– April 97</i>	<i>Control Data</i>
ADA lexical decision	Spoken	160		128	153–160
	Written	160		115	154–160
PALPA Regularity Reading (no.35)	Regular	30	28	23	29–30
	Exception	30	16	8	29–30
Surface list	Regular	126		84	n/a
	Exception	126		59	n/a
NART				3	27.6 (<i>SD</i> 10.1)
TROG		80	73	66	78.8 (<i>SD</i> 1.8)
ADA repetition	Word	40		40	31–40
	Nonword	40		33	21–40
Digit span	Forward			4	

IW's scores on a range of comprehension and naming tests are shown in Table 3. Her score on the PALPA spoken word-picture matching test (Kay et al., 1992) had declined from 34/40 when she presented initially to 18/40 in July 1996. She achieved a similar score on the written version of the same test

(22/40). Her performance on this assessment reflected her clinical presentation of poor single word comprehension in that for 20 items in the spoken version and 17 occasions for the written version, IW was unable to pick any of the 5 pictures because she had "no idea" what the words meant.

Table 3. *Assessment of comprehension and naming*

	<i>Condition</i>	<i>No. of Items</i>	<i>April 95– Sept 95</i>	<i>July 96– April 97</i>	<i>Oct 97</i>	<i>Control Data</i>
PALPA word-picture matching	Spoken	40	34	18		35–40
	Written	40		22 (32)	28	35–40
Within-category word-picture matching	Spoken	100		82	69	96–100
	Written	100		84		96–100
Hodges & Patterson word-picture matching	Spoken	48		37		47.4 (<i>SD</i> 1.1)
Shallice & McGill word-picture matching	Concrete	30		14		27–30
	Emotion	15		7		11–15
	Abstract	30		8		21–29
ADA synonym matching	Spoken	160		112		152–160
	Written	160		107		155–160
Boston Naming Test		60	12	7	7	42–60
Naming line drawings		240		73	51	228–240

To encourage responding in the remainder of our assessments, IW was given a very simple two-alternative forced-choice word-picture matching test, for which she was asked to pick a picture even if she was uncertain of the word's meaning. She achieved a perfect score for the high familiarity targets (40/40) and a slightly lower total for the low familiarity version (36/40) but importantly she had responded positively for every item. Following this "training", the PALPA written word-picture matching test was re-administered and IW was told that she must make a response to every item². Her previous score was boosted to 32/40. On a within-category word-picture matching test, IW's scores were worse than elderly control subjects (Lambon Ralph, Ellis, & Sage, 1998a) and her performance on the spoken version had declined further by October 1997. On a similar test devised by Hodges and Patterson, IW's score of 37/48 was again outside the normal range. When IW was presented with the much harder Shallice and McGill word-picture matching assessment (Shallice & Coughlan, 1980), her performance was only significantly above chance for the concrete items. IW's scores for both versions of the ADA synonym judgement test (Franklin et al., 1992) were extremely poor and she only performed above chance for the high-frequency items (spoken version: high frequency—35/40; low frequency—25/40; high imageability—27/40; low imageability—25/40; written version: high frequency—33/40; low frequency—20/40; high imageability—30/40; low imageability—24/40).

IW's poor word finding was confirmed by two tests of naming to confrontation. On the Boston Naming Test (Goodglass, Kaplan, & Weintraub, 1983) her initial score had declined a little by July 1996. IW's ability to name a selection of simple line drawings was poor in July 1996 and had reduced by 30% when assessed again in October 1997. Although IW did make some semantic errors (e.g., *leopard* → "lion"; *glove* → "handbag"; *cabbage* → "vegetable") her most common error was either to make no response or to produce a circumlocution

(e.g., *slide* → "the children climb up there and slide down"; *rocket* → "the thing that goes above the blue sky"; *caterpillar* → "the little one that comes [turns?] into a flying animal ... many different colours").

In summary, IW's performance across a range of neuropsychological assessments and pattern of circumscribed left temporal atrophy most pronounced at the pole is consistent with previously reported cases of progressive fluent aphasia (Hodges & Patterson, 1996; Hodges et al., 1992). IW presented with poor comprehension, profound anomia without phonemic paraphasia, and surface dyslexia but preserved single word repetition, object recognition, spatial skills, nonverbal reasoning, and day-to-day (episodic) memory.

Word vs. picture comprehension

When IW was being tested it was clear that although she often was unable to retrieve the meaning of words, if she was presented with a picture she could give specific information within her circumlocutory response. We decided to compare her ability to define pictures and their corresponding names, using a set of pictures consisting of 30 "animate" items (animals, plants, fruit and vegetables), and 30 objects. The sets were matched for word frequency, imageability, concreteness, operativity, age of acquisition, word familiarity, and phoneme and syllable length. For each administration of the 60-item test, IW was presented with either a picture of the object/animal, its spoken name, or its written name (counterbalanced across three testing sessions such that each concept was presented once during each session). IW was asked to give as much information as she could about each stimulus. For definition of words, IW was strongly encouraged to provide any information she could, regardless of how vague it seemed to her. IW's definitions were scored in the following way. A picture definition was scored correct if IW either named the picture correctly (on the assumption that detailed semantic knowledge is required for picture naming—when

²For the remainder of the assessments, IW was required to make a positive response even on those occasions when she felt she had no idea what the word meant.

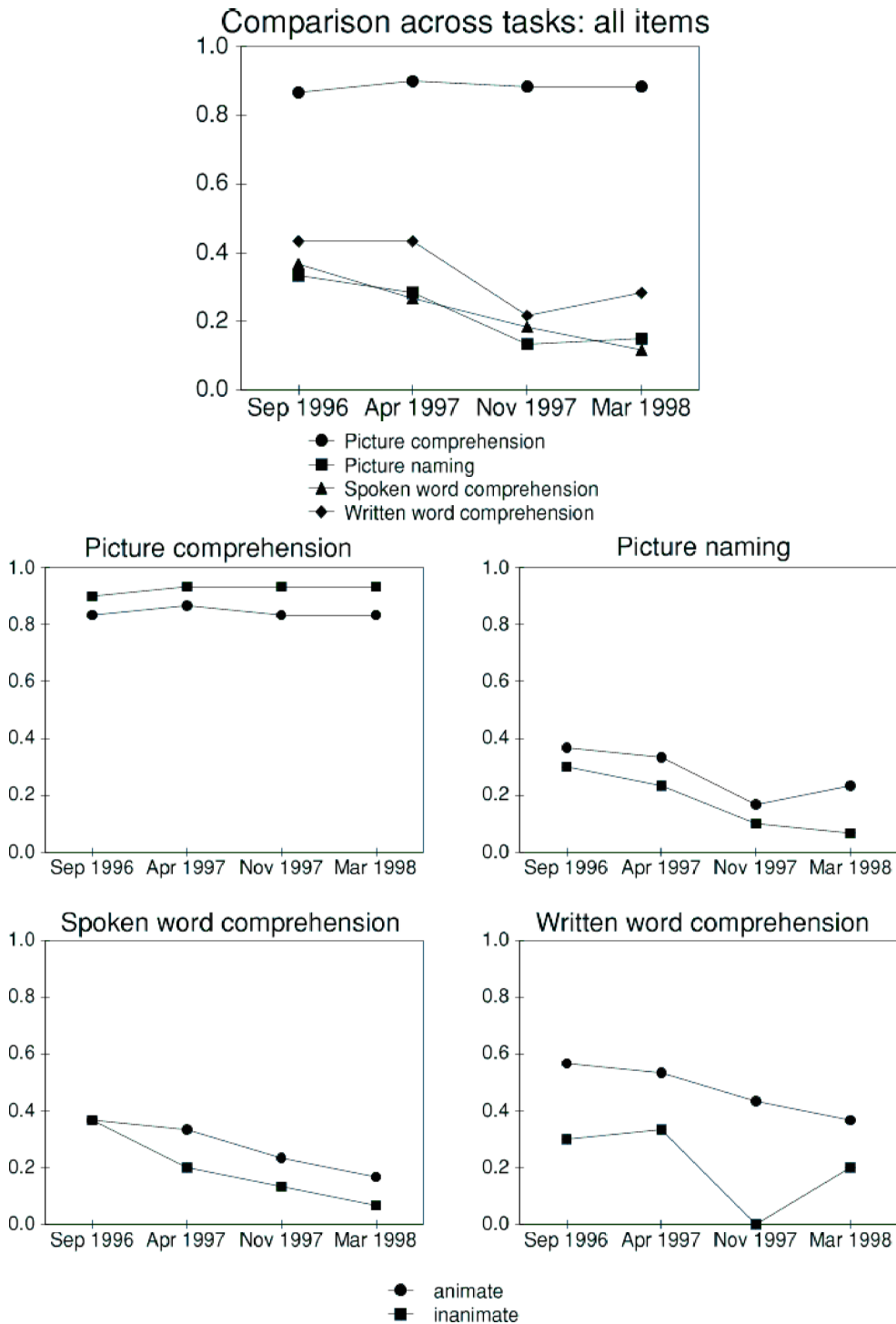


Figure 3. Longitudinal assessment of picture comprehension and naming, spoken and written word definition.

the picture was correctly named IW could always provide item-specific semantic information) or provided specific information unique to that item, which was not a visual feature discernable in the picture (e.g., *cot* → “For children. For babies. For coming up to a year old. Then they let them in a bed”; *calf* → “The baby of a cow”; *ladder* → “What we climb up. We’ve got two in our garage. The men use them when they come to wash the windows”). Word definitions were scored as correct if IW provided specific information unique to that item (e.g., *garage* → “Where we park our car”; *cow* → “The animal we get milk from”; *pig* → “That’s the animal. The little fat ones. A pork meal”).³ The results are shown in Figure 3. The top panel shows IW’s picture naming, picture definition, and written and spoken word definition assessed four times across an 18-month period. IW was consistently better at providing information to pictures than to either their spoken or written names. Her ability to name the pictures or define their spoken or written names declined in parallel over the testing period. Though not perfect, her ability to define the pictures remained relatively stable over the same time interval. The lower four panels show her performance on each task split by semantic category. As reported previously (Lambon Ralph et al., 1998c), IW’s performance across the various tasks (except for the high accuracy observed in picture comprehension), and across time, favoured animate things.

We noted earlier that IW was able to score as well as control subjects on the silhouette identification subtest from the VOSP battery (see Table 1). Despite the fact that the silhouettes provide no internal structure and are typically presented in a noncanonical orientation, IW was able to provide a great deal of appropriate information about these stimuli. To assess this more formally, we took all the silhouette items from the VOSP (the items from the silhouette identification subtest and target silhouettes from the object decision component)

and asked IW to provide as much information as she could about each silhouette or its associated name (counterbalanced across two sessions). Each definition was scored correct if IW produced information unique to that item (e.g., *grand piano* → “is that the one where you (mimes playing the keys)? Some are straight up as well. Begins with ‘p.’”; *camel* → “Is that the animal? Begins with ‘c’. It has the two lumps on its back ... and you can sit in between”). Note that some of the silhouettes are extremely difficult for normal subject to identify, however we included them in the test (and any poor responses made to them by IW) as it favours the null hypothesis of no difference between comprehension of silhouettes and their names. If her definitions are scored in this way, IW produced 37/50 correct definitions to the silhouettes but a significantly lower number to their spoken name (25/50: binomial, $p = .008$).

Our final comparison of IW’s picture and verbal comprehension used the Pyramids and Palm Trees test (Howard & Patterson, 1992) in either its all-picture or all-written-word versions. In the version with three written words, the words were also read to IW to circumvent any surface dyslexic reading errors. IW had been given the picture version when she had first presented (in 1995). At this time she was able to match pictures on the basis of association without error. When assessed a year later (July 1996) IW scored poorly on the word version (37/52: 32/52 and above is significantly above chance) but much better on the picture version (45/52). The two versions were repeated again in October 1996. This time her performance on the picture version was virtually unchanged (44/52) but the word version had to be abandoned after 15 items because IW had no idea which was the correct word and her responses were apparently made at random (7/15 correct).

The assessments reported in this section formally document the difference noted clinically—

³When IW’s responses were re-scored by another rater, without reference to the original scores (those reported here), the inter-rater reliability for the 180 trials (60 concepts repeated across 3 modalities) was extremely high for each of the 4 testing periods (95–97% agreement).

IW's verbal comprehension was significantly worse than her understanding of the same objects whether presented as simple line drawings or reduced to a noncanonical silhouette. In addition we found that although her picture comprehension remained relatively stable her verbal comprehension declined further over time.

Formal assessment of within- and between-task consistency

IW's performance seemed to be very consistent, not only within picture naming and definition tasks over time, but also between these different tasks. Indeed when IW was able to give a definition for a word and the picture, she often gave exactly the same information word-for-word (e.g., *lemon* (spoken) → "Is that the situation when we have a gin and tonic? I have that. It's yellow"; *lemon* (written) → "Lemon, which even I have a slice in my gin and tonic"; *lemon* (picture) → "That looks like a lemon"). If IW's picture naming, and spoken and written word comprehension did exhibit significant item-by-item associations within a task over time, and across the three tasks, it would suggest that her poor verbal comprehension and anomia arose from an impairment to a cognitive process shared by all three tasks. We present a formal analysis of her within- and between-task consistency based upon the 4 administrations of the 60-item definition and naming test reported earlier.

Our previous report on IW (Lambon Ralph et al., 1998c) included analyses of IW's accuracy in all three tasks for the data collected in sessions 1 and 2. These revealed that her performance was related to a number of properties of the items—length (with better performance for longer words), frequency,

familiarity, imageability, age-of-acquisition, operativity, and animacy. Given this one would, then, necessarily expect to find some consistency (cf. Behrmann & Bub, 1992; Coltheart & Funnell, 1987; Howard, 1995). Some items will always be hard, because of a combination of their properties, and thus be consistently inaccurate. Other items will be easy and so consistently accurate.

A logistic regression model was used to evaluate between- and within-task consistency. This used performance across sessions 1 and 2 in each of the tasks to predict accuracy in sessions 3 and 4 in each of the tasks (i.e., session—1 and 2—was included as a predictor variable). So for example, in evaluating consistency between spoken word definition and picture naming, the predictors were session and spoken word definition score. In order to partial out the influence of the various psycholinguistic factors noted earlier, the regression equation also included terms for each of these predictor variables. The resulting Wald statistics for each of the different task pairings, reflecting the degree and significance of within- and between-task consistency, are shown in Table 4.

This analysis indicates that the consistency within and between tasks was not an artefact of the effects of the psycholinguistic variables on IW's accuracy. Her performance was more consistent than would be expected on the basis of the effects of the variables. If greater consistency had been found within task than between task—where, for example, written word definition predicted written word definition much better than picture naming or spoken word definition—then this would favour sources of impairment specific to each modality. However, Table 4 shows that there is little differ-

Table 4. Within- and between-task (picture naming, spoken and written word definition), item consistency after controlling for the influence of eight psycholinguistic factors

	Performance in sessions 3 and 4 in:					
	Picture naming		Spoken word definition		Written word definition	
Predictor: Sessions 1 & 2 of:	Wald (1)	<i>p</i>	Wald (1)	<i>p</i>	Wald (1)	<i>p</i>
Picture naming	6.84	.0089	8.72	.0031	8.06	.0045
Spoken word definition	5.77	.0163	11.11	.0009	11.51	.0007
Written word definition	4.37	.0366	6.29	.0121	11.36	.0008

ence between within- and between-tasks consistencies, implying a common locus as the major source of her difficulties in these tasks.

Comment

We were able to use the 4 administrations of the 60-item test to assess IW's within- and across-task consistency. Importantly, for considering the locus of IW's Gogi aphasic symptoms, these analyses demonstrated significant item consistency both within and between tasks. It should be noted that the analyses were stringent in two regards. First, the consistency was significantly greater than that predicted by the eight psycholinguistic factors included here (Behrmann & Bub, 1992; Coltheart & Funnell, 1987; Howard, 1995). Second, item consistency was calculated using IW's performance in sessions 1 and 2 to predict her scores in sessions 3 and 4. In the 12-18 month-intervening period her overall accuracy had reduced by a factor of two. Consequently the method of analysis adopted here is heavily loaded against finding item consistency.

The shared within- and between-task consistency most probably reflects damage to a single system that is tapped for comprehension of spoken and written words, and picture naming. Although the analyses suggest a single common deficit, they are not diagnostic in terms of whether the impairment occurred within a semantic lexicon, a dedicated verbal semantic system, or whether it arose from damage to a unitary semantic system that had less effect on object comprehension due to the non-arbitrary mapping between pictures and their associated meaning. In the next three sections we report the results of our experimental investigation designed to assess which was the most likely locus of IW's poor verbal comprehension.

The status of IW's lexical representations

IW performed extremely poorly, although significantly better than chance, in both spoken and written lexical decision (see Table 2). Her inability to

differentiate words from phonologically plausible nonwords presented in either modality would seem to favour a lexical impairment explanation of her overall data—i.e., a lexical deficit leading to poor comprehension and recognition of spoken and written words plus profound anomia. IW might have performed poorly in lexical decision, however, because she based her responses primarily on whether she could understand the word; in this case poor lexical decision need not provide direct evidence on the status of IW's lexical representation. It is possible then that the two alternative hypotheses could also explain this aspect of her data. We conducted four specific experiments designed to investigate the functioning of her lexical representations further, using techniques that draw on lexical representations, implicitly. The results are reported next.

Repetition priming in object vs. lexical decision

In the first assessment we contrasted repetition priming for objects and written words. For objects, IW was presented with a simple line drawing and was asked to decide whether the stimulus was a real object or a nonsense figure (an abstract form containing no parts of real objects). Pictures of real objects ($N = 120$) were intermixed with nonsense figures ($N = 120$) and were presented singly on a portable computer for 1750 ms (ISI 250 ms). IW was asked to press one of two buttons to indicate whether the picture was real or not. The 240 stimuli were presented in 8 equally sized blocks (30 trials each). The procedure for the written words was identical. IW was presented with 120 written words intermixed with 120 consonant strings and she was asked to indicate whether the written string was a word or a nonword⁴. Amongst the 120 real item trials included in this experiment, we presented 28 real pictures and words twice with at least 1 block (30 trials) between first and second presentations.

IW's overall accuracy for the timed picture decision (236/240) and lexical decision (229/240) tasks was good. For the priming subsets, IW made no errors for the picture stimuli and only four errors for the written words. IW demonstrated a substantial

⁴As noted earlier, IW was very inaccurate at lexical decision if the nonword foils were relatively word-like. We had found that her decision accuracy was much better if the foils were less word-like, in this case consonant strings.

reduction in reaction time for the pictures (response time for first presentation: mean = 861 ms, $SD = 208$ ms; second presentation: mean = 641ms, $SD = 92$ ms) and the words (response time for first presentation: mean = 802 ms, $SD = 233$ ms; second presentation: mean = 606ms, $SD = 87$ ms). Item analysis by ANOVA revealed a significant main effect of priming, $F(1, 23) = 42.3$, $p < .001$, but no effect of modality, $F(1, 23) = 2.07$, $p = .16$, nor an interaction; $F(1, 23) < 1$. Thus, not only did IW demonstrate a substantial and significant repetition priming effect (in the order of a 25% reduction in her decision times), the effect for words and pictures was statistically equivalent.

Word span

If IW's lexical representations were functioning, her span for words should be longer than for nonwords, even for those real words she was no longer able to comprehend. From the set of 60 items, which IW had been asked to define in spoken and written form and to name as pictures, we selected 2 sets of 10 items. The "known" words were items for which IW had provided good definitions for both the spoken word and the written word and had named the picture correctly. For the "unknown" words, IW had been unable to provide any relevant information in defining both the spoken and written word and had not named the pictures correctly. The "known" and "unknown" word sets were matched for length in number of phonemes and number of syllables, Francis and Kucera (1982) word frequency, and numbers of shared phonemes using Lhermitte and Derouesne's (1974) "index of phonemic similarity". It did not, however, prove possible to match the sets for other psycholinguistic properties: the "known" words were significantly higher in ratings of concreteness, and imageability and lower in rated age of acquisition than the "unknown" items. A set of 10 nonwords was also selected, matched to the real word sets in numbers of phonemes, syllables, and in terms of the "index of phonemic similarity".

Spans for each set of items were assessed using the "staircase" method. The first list presented of each type was of length two. On each trial, if the list was recalled correctly with items in the correct order the next list of that type presented was one item longer, or if the list was incorrectly recalled the next list was one item shorter. Before each list, IW was informed how long the list was to be. Items were spoken at one item per second, and spoken recall was cued with a hand gesture. Lists of "known" and "unknown" words were alternated within a block, but non-words were presented in a separate block. There were 50 trials for each type of real word. The lists of "known" and "unknown" words were tested on two occasions, but the nonwords were tested once with only 20 trials. Span was estimated as the mean length of the lists presented, discounting the first trial of each type but the length of the last (unpresented) list was included. As the lengths of the lists presented are not independent of each other conventional statistical tests could not be used. The results were analysed using a randomisation (Monte Carlo method) test. IW's performance was used to estimate the probability correct on lists of each length on the null hypothesis that this was equal for both types of list (Edgington, 1987). Then 99,999 pseudo-experiments were run to estimate the probability of a difference in span between the list types equal to or larger than that obtained in the experiment with IW.

IW's span was 2.98 for known words, 2.82 for unknown words, and 2.20 for nonwords. The difference between IW's performance for both types of real words and the non-words was significant, by the randomisation test ($p < .001$, one-tailed, in both cases). The slight difference between the spans for "known" and "unknown" words was not significant ($p = .264$, one-tailed). Recall accuracy for these items for lists of different lengths are shown in Figure 4. This illustrates that there was a substantial lexicality effect in list recall, but that there were minimal and non significant differences between "known" and "unknown" words⁵.

⁵We originally ran 20 trials in each condition. This revealed a significant lexicality effect but no difference between known and unknown words. In an attempt to find a known/unknown difference we administered another 30 trials in each condition, though as the overall results reported here show, we found no evidence for the known-unknown difference in IW.

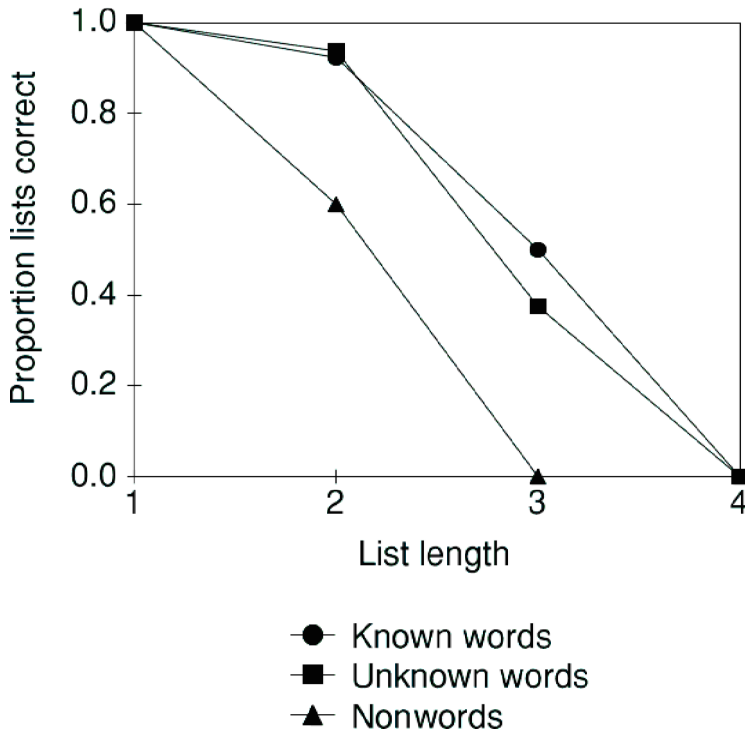


Figure 4. Proportion of word lists recalled for “known” words, “unknown” words and nonwords.

We note in passing that these results are slightly different to those found in other patients with progressive fluent aphasia reported by Patterson and her colleagues (Knott, Patterson, & Hodges, 1997; Patterson, Graham, & Hodges, 1994). Although these patients are able to repeat single words without error, when they are asked to repeat a string of words they begin to make phonemic migration errors. The majority of patients exhibit significantly better span performance for “known” than “unknown” words—a result that seems to indicate that conceptual knowledge may help to maintain the integrity of the phonological word-forms stored in short-term memory, preventing phonemes from migrating from one word to another: the *semantic binding effect* (Knott et al., 1997). Knott et al. describe one patient, however, who demonstrated much smaller semantic effects in word span tasks. In explaining the difference between these patients, Knott et al. argued that the underlying semantic binding effect may be most prominent in patients

who have an additional post-semantic deficit that (a) causes phonological activation to decay abnormally quickly, or (b) leads to inadequate phonological activation of the target word in the first place. If this hypothesis is correct then it adds to our evidence that IW’s poor verbal comprehension had a semantic locus and did not arise from a non-semantic deficit (see the Comment following).

Same/different judgements of written words

In the second priming experiment we utilised another simple experimental paradigm—same/different judgements of written words and nonwords. Judging if strings of visually presented letters are the same or different is a task that only necessitates access to a visual description of the stimulus. However, normal subjects make these judgments more rapidly if the stimuli are real words than if they are nonwords (Friedrich, Walker, & Posner, 1985). This lexicality effect must depend on having lexical representations for the items involved. In this

experiment we used same/different judgments on letter strings to investigate whether the words that IW cannot use as names or define as spoken or written words are lexically represented.

The experimental items were generated from the 60 items that IW had been asked to define as spoken and written words, and to name as pictures, plus an additional set of 5 words which served as practice items, at the start of each block. There were 5 kinds of stimuli:

- (1) Real words "same" judgements:
e.g., TOMATO TOMATO
- (2) Nonwords "same" judgements:
e.g., TORATO TORATO
- (3) Real word/nonword "different" judgements:
e.g., TOMATO TORATO
- (4) Nonwords "different" judgements:
e.g., TOMAGO TORAGO
- (5) Real words "different" judgements:
e.g., MEDAL METAL

Lexicality effects could be observed either in faster "same" judgements for real word pairs than with nonword pairs, or in faster "different" judgements for real word/nonword pairs than with nonword pairs. Non-matching pairs had differences at the beginning of the word, medially or at the end with equal frequency. Position and identity of the difference was always identical for the word/nonword pairs and nonword control pairs. The pairs of different real words were included to make it impossible for IW to conclude that a pair was the same on the grounds that both were real words. The items were presented in five blocks, each of which began with five practice items. Equal numbers of stimuli of each type were included in each block, and the order of items from each quintuple of pairs

was the same in each block. As a result 64 judgements intervened between the presentation of any of the item pairs generated from any one stimulus item. The pairs of items were presented simultaneously one above the other in upper case on the centre of a VDU screen, following an auditory warning and two fixation lines that bracketed the position in which the stimuli would appear. The items remained on the screen until a response was made. IW was instructed to decide as rapidly as possible whether the items had exactly the same letters and responded by key presses with her left hand (for yes) or her right hand (for no). Two seconds elapsed between a response and the presentation of the subsequent stimulus. There was an opportunity for a rest between each block.

The results are shown in Table 5. IW's accuracy in this task was excellent, with a total of only 1% errors. In analysing the reaction time data, errors were excluded, as well as 6% of the RTs that were more than two standard deviations from the mean for that cell. The RTs reported in Table 5 are based on these data where RT data remained for both the real word stimulus and its nonword control. On the "different" judgements, there was no difference between judgements involving a real word and a nonword and those with a matched set of two nonwords, $t(53) = 0.24$, n.s. With "same" judgements, however, IW was 215 ms faster with real word pairs than the control non-word pairs; this lexicality effect was significant, $t(51) = 3.50$, $p < .001$. The extent of the lexicality advantage was not, however, related to IW's ability to produce or understand the words: When the degree of lexical advantage for each item was correlated with IW's ability to understand the spoken words, and written words or to name the corresponding pictures, there was no sig-

Table 5. Accuracy and decision times for same-different judgements

<i>Stimulus type</i>	<i>Example</i>	<i>Proportion correct</i>	<i>Mean decision time (SD)/ms</i>
Real word—same	TOMATO - TOMATO	1.00	1473 (358)
Nonword—same	TORATO - TORATO	1.00	1688 (410)
Real word/nonword—different	TOMATO - TORAGO	.98	1565 (489)
Nonword—different	TOMAGO - TORAGO	.97	1574 (529)
Real word—different	MEDAL - METAL	1.00	1336 (225)

nificant relationship $r(52) = .11$, n.s. This result was confirmed with the matched subsets of "known" and "unknown" used in the word span experiment. For "known" words the lexicality advantage was 176ms and for "unknown" words it was 201 ms.

Repetition priming of real-word and nonword targets in lexical decision

The results of the previous experiment and the word span assessment converge. IW performs better with real words than with matched nonwords in both tasks. However, there is no relationship between the extent of the real word advantage and IW's comprehension of these words. The clear conclusion is that, although IW shows a consistent semantic deficit for individual items, lexical representations that support the real word advantage are intact for both the items for which IW has a semantic impairment and those that are semantically, relatively intact.

This experiment seeks further evidence in support of this conclusion from another repetition priming experiment. Lexical decision for a real word is faster when this item is subsequently re-presented, than when it was presented for the first time (e.g., see Monsell, 1991; Morton, 1969). When the interval between first and second presentation is more than a few items this effect is not typically found for nonwords. This repetition priming effect, therefore, demonstrates that the real words are lexically represented. In this experiment, we seek evidence that there is repetition priming in visual lexical decision for real words, and not nonwords, and investigate whether the extent of this priming is greater for words for which IW is semantically impaired compared to those for which her performance shows that semantic representations are relatively intact. If words that IW does not know are no longer represented at the lexical level (which supports long-term repetition priming), lexical decision RTs should be no faster on the second occasion the words are presented for lexical decision; the priming effects should be confined to the items that she still comprehends and produces.

This experiment involved the 60 items that IW had defined as spoken and written words and pro-

duced as picture names. They were presented for lexical decision together with a set of nonwords, which were derived from the real words by random re-arrangement of the letters. The items were tested in two sessions. Each session was divided into two halves. In the first half, 30 of the items and 30 nonwords derived from the other 30 real words were presented for lexical decision, together with a further set of 30 real words and 30 nonword fillers. In the second half of the session, the 30 real words and 30 nonwords were presented for lexical decision together with a further set of 30 nonwords and 30 real word fillers which had not previously been presented. In the second session, the other 30 target words were presented on 2 occasions, together with repeated nonwords derived from the real words presented in the first session. Non-repeated filler real words and nonwords were presented as before in both halves of the session. Two practice items were presented at the beginning of each half of each session. The lag between first and second presentation of real words and nonwords was 61 intervening items in each case. Items were presented for lexical decision following an auditory warning and a fixation spot, which preceded the stimulus by 300 ms. Stimuli were presented in upper case in the centre of the VDU screen and remained until a response was made by IW. A pause of 1500 ms followed IW's response before presentation of the next stimulus. There was no pause between the two halves of the session. IW was instructed to press a specified key with her left hand if the item was a real word and another key with her right hand if it was a nonword.

The results are shown in Table 6. Overall IW made 5% errors in this task with more errors to nonwords (7.5%) than real words (2.5%). Some of her responses, especially with nonwords, were very slow and RTs more than 5000 ms were excluded from the analysis, eliminating a further 5% of responses to real word trials and 22% of responses to nonwords. Overall correct responses to nonwords were 522 ms slower on second presentation than on the first presentation within the session $t(41) = 3.17$, $p < .01$, two-tailed. In contrast, the second response to real words was 359 ms faster than when they were first presented $t(55) = 4.74$, $p < .001$.

Table 6. Accuracy and decision times for the repetition priming lexical decision experiment

Stimulus type	First presentation		Second presentation	
	Proportion correct	Mean decision time (SD)/ms	Proportion correct	Mean decision time (SD)/ms
Real words	.97	1655 (683)	.98	1296 (574)
Nonwords	.95	1956 (870)	.90	2478 (1041)

There was, therefore, a significant reduction in decision times (i.e., repetition priming) for real words but not for nonwords.

The critical question is whether this repetition priming effect is modulated by the degree to which semantic representations for these lexical items are intact. Correlating IW's performance in defining and naming these items with the size of the repetition priming effect yielded $r(52) = -.177$, n.s. This result was corroborated when the subsets of matched "known" and "unknown" words were considered; the priming effect for "known" words (92 ms) was equivalent to that for "unknown" words (105 ms). Thus IW exhibited repetition priming that occurs only with real words and is unrelated to her comprehension.

Comment

The results of these previous experiments, which employ very different techniques, converge. IW exhibited equivalent repetition priming effects for decisions made to words and pictures. Most importantly, across all of the last three tasks IW performs significantly better with real words than with matched nonword stimuli and the degree of the advantage is unrelated to her comprehension accuracy. The conclusion is clear: The lexicity advantage in these tasks is mediated by non-semantic lexical representations⁶. There are two possible explanations of IW's poor verbal comprehension. If there are both modality-specific lexical representa-

tions (e.g., a visual input lexicon, a auditory input lexicon, a speech output lexicon) in addition to an amodal semantic lexicon, then it is possible to argue that IW's poor verbal performance arose from an impairment to the semantic lexicon, but the lexicality effects in repetition priming, visual matching, and word span tasks reflected normal functioning of various modality-specific lexical representations. Alternatively, her differential comprehension impairment could have arisen from a semantic impairment—either to a dedicated verbal semantic system or to a unitary system in which the effects of object affordance are taken into account. These latter possibilities are explored in the following sections.

A verbal semantic impairment?

IW's poor comprehension of words and severe anomia could reflect a selective impairment to a verbal semantic system leaving the remaining visual semantic system to support, for example, her excellent definitions of objects presented as pictures or silhouettes. The item consistency observed across input modalities (written vs. spoken presentation) is easily explained by this theory: If a selection of concepts has been severely degraded or even removed from the verbal semantic system, IW should be unable to provide any information about these items whether presented in written or spoken form. Note that unlike the lexical impairment hypothesis discussed earlier, the multi-modal

⁶One could argue that the significant lexicality effects noted in these experiments reflect *normal* functioning of *intact* lexical representations. Lexicality effects could remain, however, even if the lexical representations were partially degraded. The conclusions drawn with regard to the locus of IW's poor verbal comprehension remain unchanged whichever position is correct. If her poor comprehension were due to a lexical impairment then the size of the lexicality effect should be related to her comprehension accuracy. In contrast, IW exhibited significant and substantial lexicality effects for both "known" and "unknown" words.

semantics hypothesis also allows for “unknown” words to activate pre-semantic representations leading to the lexicality effects described in the previous section.

If this position is correct then when IW was unable to define a word she should have been unable to demonstrate its meaning in any other circumstances. Her performance on purely verbal tasks such as word definition and synonym judgments, however, seemed to be somewhat lower than when words were presented with a selection of semantically-related pictures, as in word-picture matching tasks. If poor verbal comprehension reflects impairment to the verbal semantic system then the pictures in the word-picture matching tests should access their full conceptual representation, and the target name should activate the pre-semantic lexical item, but the name of the target picture and its picture-driven visual semantic representation will be prevented from “making contact” because this requires access to the (lost) corresponding verbal semantic representation. Consequently when the patient is unable to understand a word, she or he should be unable to match it to the appropriate picture—i.e., she or he should, as IW did initially, make no response errors in word-picture matching tasks. We were able, however, to encourage/train IW into making positive responses in all these tasks (see Table 3). Two specific clinical observations are noteworthy. When unsure about the meaning of the target name, IW typically looked round the pictures presented on the page as though looking for clues to the word’s meaning. We were able to encourage IW’s positive responses following the use of a simple two forced-choice word-picture matching task (see earlier). To introduce IW to this assessment, we used a number of items from an identical task in which the close-semantic foils were replaced with pictures of unrelated items. IW’s comment to one of the trials is not only instructive, it inspired the two experiments reported next. In one trial, the subject is presented with the word “*pram*” and is asked to decide between the pictures of a *pram* or a *hammock*. IW picked the target picture and said, “... but if you had said what’s a pram I wouldn’t have thought about babies.” When asked 5 minutes later, “what is a

pram, tell me anything you know about a pram,” IW replied, “I don’t know what a pram is.”

The first experiment used the items from the Pyramids and Palm Trees test (PPTT: Howard & Patterson, 1992). The target items (e.g., *pyramid*) were presented to IW in written form (and were read aloud by the examiner) for definition. In one condition, the target word was presented with the picture of the correct response from the test—i.e. the most closely related item (e.g., *palm tree*). In the control condition, the word was presented with the foil picture (e.g., *fir tree*). The two conditions were counterbalanced across two testing sessions. For each trial, IW was instructed to look at the picture and was informed that it may or may not be related to the meaning of the word. After looking at the picture IW was asked to give as much information as she could about the word regardless of how vague it seemed to her (note, this technique is similar to that used by Franklin, Howard, & Patterson, 1994).

IW’s definitions were scored in two different ways. A definition was scored correct if IW produced at least one correct piece of information about the target word. Second, the number of attributes produced for each word was compared across conditions. On the basis of the first scoring method, IW only produced 4 more definitions in the associated-picture condition (control condition: 29/52 words were defined; primed condition: 33/52 words). Although the absolute number of words defined did not significantly increase, the quality of IW’s definitions were improved—i.e. she produced a significantly greater number of features in the primed condition (mean number of features produced per item: control condition = 0.95; primed condition = 1.40: Wilcoxon matched-pairs sign-ranks test, $z = 2.65$, $p = .008$).

The results of the previous experiment might be improved if the priming picture bore a more direct relationship with the target word. We assessed this possibility with a second definition priming experiment. Twenty-eight words were selected from the 60-item set used for definition and lexicality experiments noted earlier. These 28 words were selected because IW had been unable to define them from written or spoken forms (in September 1996 and

April 1997). Thus the meaning of these words appeared to be lost from her verbal semantic system. Each target was paired with a semantically related item that acted as the picture prime (e.g., a picture of a *buckle* for the word *button*). In the control condition the target word was presented with an unrelated picture (the prime pictures pseudo-randomly reordered so that there was no relationship between word and picture pairs). The experimental and scoring procedures were identical to the previous experiment.

When IW was presented with a semantically related picture prime both the quantity and quality of her word comprehension improved. The number of definitions given in the control condition (5/28: 18%) increased significantly (14/28: 50%;—Binomial, $p = .002$). As in the previous experiment, the picture primes also increased the quality of IW's definitions (mean number of features produced per item: control condition = 0.25; primed condition = 1.46: Wilcoxon matched-pairs sign-ranks test, $z = 3.3$, $p = .001$).

The results of these two priming experiments do not seem to fit with the multi-modal semantics hypothesis in which IW's poor verbal comprehension is explained by a selective impairment of the verbal semantic system (at least in a simple version of this theory—see the Discussion later). If a selection of concepts had been removed or were completely inaccessible from the verbal semantic system, IW's comprehension of these words should have been unaffected by the circumstances in which they were presented. We have been able to demonstrate, however, that IW could access at least some aspects of those words she could not normally define if they were presented with a picture of a closely related concept. It would seem that the benefits afforded by picture input to semantics are able to spread to word comprehension (see the Discussion later for an extension of this argument with

respect to the connectionist network described earlier)⁷.

Impairment to a unitary semantic system?

As noted in the Introduction, theorists who adopt a unitary model of conceptual knowledge argue that there is an underlying difference between word and picture comprehension. An impairment to a unitary semantic system should have a greater impact on word comprehension because surface form and meaning have an arbitrary relationship. The multi-modal semantics and semantic lexicon hypotheses suggest that poor word comprehension reflects damage to a separate cognitive component. Thus, differential performance does not stem from an underlying difference but is truly evidence for a dissociation between visual and verbal semantics, or conceptual knowledge and a semantic lexicon, respectively. If relatively poor verbal comprehension arises from a deficit within a unitary semantic system then it should be possible to find evidence of at least subtle impairments to nonverbal comprehension. The alternative hypotheses do not make this prediction—it should be possible to have impaired verbal comprehension without any impact on the remaining conceptual knowledge. Although IW performed worse on the word version than the picture version of the PPTT, it should be noted that IW had been given the picture version a year before the bulk of our experimental investigations began. As noted earlier, IW initially performed flawlessly on the picture version of the PPTT but her accuracy had declined to 45/52 by July 1996. This would seem to indicate that IW's non-verbal comprehension had not been completely spared. The final selection of observations and experiments reported next explore this possibility further.

⁷One could argue that the “priming” effect noted here, in fact, reflected a strategy in which IW utilised her good picture comprehension to give defining information derived directly from the semantically related picture rather than to the target word itself. We think this is very unlikely for two reasons. First, at this stage IW was often able to give item-specific information for pictures—and thus at least some of her correct “word” definitions would have appeared to be semantic errors (e.g., saying that a *button*—in the presence of the picture of a *buckle*—was found on the end of a belt). Second, and most important, this experiment included a control condition in which the accompanying pictures were unrelated. If IW was merely defining the accompanying picture then her unrelated “definitions” for the target words would have been obvious. There was no evidence for either type of error in IW's definitions.

Poor knowledge of sensory attributes

Our previous report on IW (Lambon Ralph et al., 1998c) noted that she was particularly poor at recalling the sensory attributes of concepts relating to objects and animals (for similar results in other patients with progressive fluent aphasia, see Basso et al., 1988; Breedin et al., 1994; Lambon Ralph et al., 1999b; Moss et al., 1995; Sirigu et al., 1991; Srinivas et al., 1997; Tyler & Moss, 1997). IW was worse than normal controls when required to indicate the typical colour of real objects, produced definitions with significantly less sensory than associative/functional attributes, was less accurate when asked to answer questions relating to sensory than functional features, could match definitions to the corresponding concept better if the definition contained nonsensory information, and, relative to age-matched controls, IW typically produced only half the number of features in drawing from memory. IW's poor knowledge of sensory attributes does not seem to fit with the multi-modal view of her verbal comprehension deficit. Presumably knowledge regarding the sensory, primarily visual, attributes of objects and animals is stored within the visual semantic system, yet IW presented with poor verbal comprehension.

Knowledge of famous people from faces

If IW had a selective verbal semantic impairment she should have been able to both recognise and indicate the profession of famous personalities from their face, although we would have expected poor recall of their name. IW's knowledge of famous faces was assessed across a set of 54 famous people⁸. Each famous face is presented on a page with three unfamiliar faces. To assess recognition, the subject is required to pick which face is a famous person. IW's recognition score of 51/54 was better than the control average (44.5/54). Then for each famous face the subject is asked to indicate the person's profession and their name. IW was only able to name five of the famous faces (control mean = 34.6, $SD = 6.54$). She was also much worse than control subjects when required to indicate their profession

(IW: 23/54; control mean = 42.8, $SD = 6.55$), even though we scored her anomalous responses very leniently.

Recognition of environmental sounds

IW's ability to recognise familiar environmental sounds was assessed using sound-word and sound-picture matching tests⁹. Forty-three characteristic sounds covering seven broad categories (household items, human sounds, everyday sounds, transport, animals, musical instruments, and miscellaneous) were played to IW. After each sound, IW was asked to pick out the name of the sound (each target was presented with the names of the other sounds from within the same category). A subset of 32 sounds (for which we had recognisable pictures—i.e. not the human or everyday sounds) were presented on another occasion and IW was asked to pick out the corresponding picture from the within-category array. Six female control subjects (age 22–56 years) found both versions of the task extremely easy, each subject matching the sounds to words or pictures without error. IW was impaired on the sound-word matching test (29/43) and although slightly better when matching sounds to pictures, her performance was still worse than normal subjects (sound-picture matching: 25/32; IW's performance on the same items for sound-word matching: 19/32).

Delayed copying

We noted above that IW was only able to produce half the number of features given by control subjects when drawing from memory. We also utilised a delayed copying technique previously described by Franklin, van Sommers, and Howard (1987). Copying a picture after a delay should require the subject to use semantic as well as "visual" iconic memory. Consequently any impairment to semantic knowledge should be highlighted in this task (presumably it will be most sensitive to the status of visual semantic attributes). Amnesic subjects required little or no delay before differences are obtained between immediate and delayed copy (see

⁸This test and the normal control data relating to it were kindly provided by Andrew Ellis.

⁹The sounds for these tests were kindly provided by Wendy Best.

patient DB: Lambon Ralph et al., 1998c). IW required up to a minute delay before her poor visual knowledge began to influence her delayed copying.

Figure 5 shows a number of examples of IW's immediate and delayed copies. Although IW's immediate copies demonstrate good drawing skills, her depictions after a minute delay resemble those she produces in response to the word and suggest a gradual loss of specific visual features.

Comment

All the tasks reported in this section require access to nonverbal conceptual knowledge. Although IW's semantic impairment seemed to be specific to accessing the meaning of words (her definitions to pictures often provided item-specific information), her performance on these assessments suggests that her semantic impairment also affected nonverbal comprehension. Of course, many of the tests require verbal comprehension (e.g., drawing from memory) and/or verbal production (e.g., providing semantic information to famous faces). So the poor nonverbal knowledge revealed by these tasks is conflated with IW's generally poor verbal comprehension. This is not true of all the tasks, however, and we have been able to demonstrate an impairment beyond word comprehension using purely nonverbal assessments such as colouring, sound-picture matching, and delayed copying.

DISCUSSION

We have presented data collected from IW, a patient with progressive fluent aphasia following atrophy to the inferior, lateral aspects of her left temporal lobe most pronounced at the pole. IW presented with two striking clinical features—profound anomia and poor verbal comprehension—hallmarks of the syndrome described as Gogi, or “word-meaning,” aphasia (Imura, 1943; Sasanuma & Monoi, 1975). Although IW was nearly always able to give item-specific information to pictures (despite her anomia), she was often unable to give any information about the concept when it was presented as either a written or spoken word, nor could

she retrieve its spoken name. In fact we discovered a high degree of item consistency between picture naming, and spoken and written word definition, suggesting that IW's poor comprehension and naming—i.e., her Gogi aphasia—stemmed from an impairment to a system relied upon by these three processes.

We attempted a series of experimental studies designed to test three different theoretical interpretations of selective verbal comprehension impairment. Some authors have argued for the need of a specialised transcoding system that is able to translate between conceptual knowledge and verbal processing both for comprehension and speech production (the semantic lexicon: Butterworth, 1989; Butterworth et al., 1984; Nickels & Howard, in press). A semantic lexicon deficit should produce the symptoms displayed by IW, i.e. poor comprehension of spoken and written words, excellent picture comprehension (which can access conceptual knowledge directly), but poor word-finding abilities. The second theory places the cause for IW's poor comprehension within the semantic system itself. The multi-modal semantic theory (Lauro-Grotto et al., 1997; McCarthy & Warrington, 1986; McCarthy & Warrington, 1988; 1993; Warrington & McCarthy, 1994) would suggest that IW and patients like her form one half of a modality-specific double dissociation within the semantic system. IW's poor verbal comprehension arises from a specific impairment to the verbal semantic store, whereas other patients with relatively poor comprehension of pictures reflect an impairment to the visual semantic system. The third and final theory considered also suggests that poor verbal comprehension reflects a semantic locus but that the impairment observed in these cases is to a unitary (amodal) semantic system (Caramazza et al., 1990; Graham et al., 1997; Hillis et al., 1995; Hodges & Patterson, 1996; Lambon Ralph et al., 1999b). Rather than assuming differential verbal and picture performance reflects a delineation of conceptual knowledge (as in the multi-modal semantic theory), the unitary theories suggest that comprehension is better for pictures than words because of an underlying difference in the translation of surface form to meaning for pic-

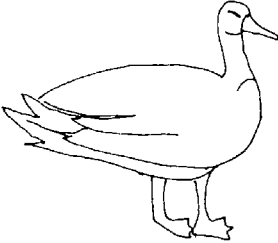
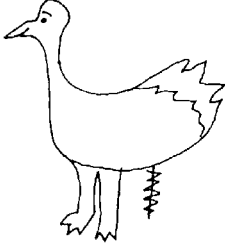
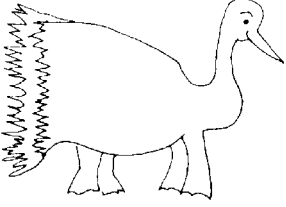
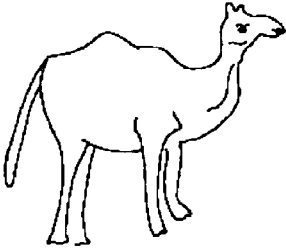
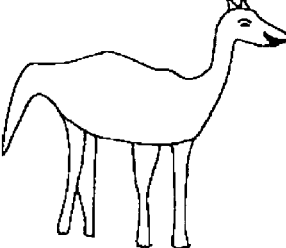
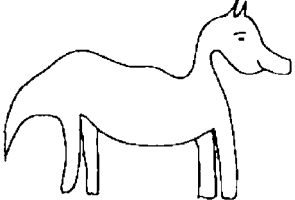
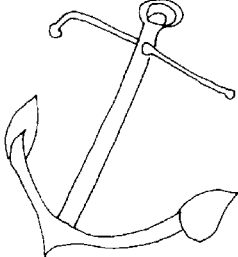
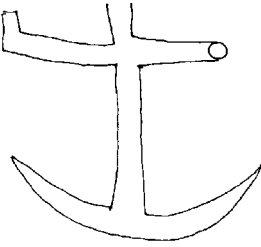
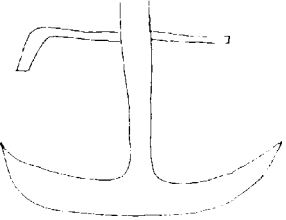

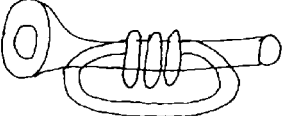
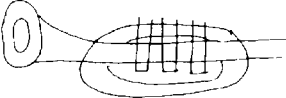
Item	Immediate Copy	10 second delay	60 second delay
Duck			
Camel			
Anchor			
Trumpet			

Figure 5. Examples of IW's immediate and delayed copying.

tures and words. Conceptual knowledge and verbal representations have an arbitrary relationship. Thus there are no patterns of phonology or orthography that give clues to word meaning. Components of living and nonliving things, on the other hand, do afford aspects of the corresponding meaning. At the beginning of this paper we were able to demonstrate that if this underlying difference is built into an implemented simulation of word and picture comprehension, an impairment to a unitary semantic system always produces better performance from picture than word input (except where performance approaches ceiling or floor).

If the data reported here are considered together, they would seem to support the unitary semantic position. The series of implicit tasks designed to contrast word and nonword processing found consistent lexicality effects and no difference between known and unknown words. It seems unlikely, therefore, that IW's poor verbal comprehension arose from a lexical impairment. We were also able to demonstrate that given the right circumstances (priming with a semantically-related picture) IW could provide information about words she was consistently unable to define when presented in isolation. This goes against the predictions of the multi-modal semantics and semantic lexicon hypotheses (at least in the strong form of these theories in which individual concepts or lexical representations are lost—see following for further discussion). These theories are based upon the notion that differential word and picture performance reflects a functional dissociation between cognitive components. Thus if words are consistently unavailable from either spoken or written input then these items must have been lost or have become completely unavailable from either the semantic lexicon or the verbal semantic system. The final set of experiments also follow from the dissociation between verbal and nonverbal processing assumed by these two theories. If the comprehension deficit demonstrated by patients like IW reflects impairment within the verbal domain then nonverbal comprehension should be preserved. The unitary theory, on the other hand, predicts that poor verbal comprehension should be accompanied by at least subtle non-verbal semantic impairment

(as long as tasks are made sensitive enough and overall performance is not close to floor or ceiling). This prediction was borne out by the data collected. IW did exhibit impaired performance in tasks that require access to nonverbal semantic knowledge even in tests that did not rely on receptive or expressive verbal skills.

All IW's results can be explained by unitary models of semantic memory that emphasise the underlying difference between pictures and words. For example in the simulation reported earlier, damage to the semantic units leads to relatively better picture than word comprehension. This is because the "picture" input representations bear a close resemblance to a proportion of the full semantic patterns. The "word" representations have an arbitrary relationship with meaning that is much more sensitive to semantic impairment than the quasi-systematic mapping between pictures and semantics. As meaning is stored within a single system, however, semantic impairment does produce a picture comprehension deficit albeit less pronounced than for words (NB: this is true except for mild levels of damage to the semantic units where picture comprehension remains at ceiling, see Figure 2). We have been able to extend this model to the semantic priming effects noted here. Taking a single example of the model with 75% of the semantic units clamped to zero produces a notable difference between picture (42/50: 84%) and word (34/50: 68%) comprehension. We compared these word comprehension results to those obtained when the semantic units were first activated by a nonidentical picture input from within the same "category" (i.e., a semantically related picture input was turned on and activation allowed to cycle for 10 time steps before the picture input was removed and replaced by the target word input). This simulated priming experiment not only improved the accuracy of the model's word comprehension (39/50: 78%) it also improved the quality—in all cases where the model continued to make an error it, nevertheless, activated the correct part of the semantic space.

The behaviour of the model can be explained in the following way. Activating exactly the right part of the semantic space can be thought of as being like

finding the proverbial needle in a haystack. As there is a direct, quasi-systematic relationship between objects and their meaning, the form of the object provides a pointer towards the correct part of the semantic space, i.e., we would know roughly where in the haystack to look for the needle. The arbitrary relationship between words and semantics, however, means that the surface form of a word provides no clues as to where in the haystack to begin searching. Picture priming of word comprehension effectively acts by "warming up" the correct part of the semantic space before the word input is initiated: The picture prime points to the correct part of the haystack before searching for the needle commences.

How do the other theories explain IW's data?

There are three main reasons why we tend to favour the unitary semantic hypothesis as an explanation for IW's data. First, as we have argued, the hypothesis provides a sufficient account. Second, any theory with one, rather than many, functional systems must be the most parsimonious option. Finally, we have demonstrated that when the assumptions of the unitary semantic hypothesis are implemented in a simple network, the full range of key behavioural characteristics observed in IW is reproduced. Although the unitary semantic hypothesis is our favoured option, it does not mean that it would be impossible to adjust the other theories to encompass IW's data. We shall briefly review the various additional assumptions required by the alternative approaches.

An impairment in a dedicated verbal semantic system would automatically produce poor verbal comprehension, anomia, and at least a degree of item consistency within and between spoken and written word comprehension and picture naming (assuming that speech production was primarily driven by the verbal semantic system). To give a full account of IW's data we must also assume that there was another, albeit milder, deficit within the visual semantic system leading to impaired drawing and delayed copying, impaired nonverbal comprehension, and so on. In order to explain IW's improved

verbal comprehension following picture-based priming of words that IW was consistently unable to define in normal circumstances, we must assume two things. First, verbal concepts cannot be "lost" under damage but rather have become incapable of being activated sufficiently by word input alone. Second, the verbal and visual semantic systems must be coupled in such a way that activation can pass between the two kinds of representation. In these circumstances, one can then imagine an explanation for the priming data. For example, the word *buckle* may only partially activate its conceptual, verbal representation and this will lead to consistently poor performance with repeated presentations. The picture of a *button*, however, will be able to activate its visual conceptual representation and, presumably, by association other similar concepts will be partially activated (including the visually based meaning of a buckle). When these two situations are combined, as they are in the priming experiment, the partial activation for the two meanings of *buckle* will reinforce each other and thus make it more likely that IW will be able to provide at least some appropriate information.

The explanation and additional assumptions for the semantic lexicon approach are rather similar. An impairment to a dedicated system that acts as a "gateway" between conceptual and language-based representations will tend to produce anomia (an inability to access output representations from conceptual knowledge) and poor verbal comprehension (although the meaning of words is still intact, it is inaccessible from spoken or written input). As the gateway is generally described in terms of localist representations, IW's item consistency follows naturally from assuming damage to some, but not all, the entries within the semantic lexicon. Again, though, we have to assume that this damage comes in the form of underactivation or heightened thresholds, which can be overcome by collateral, indirect activation from the presentation of semantically related visual input (for a discussion of the effects of partial damage or access to the semantic lexicon, see Butterworth et al., 1984). Finally, we also have to assume a mild, secondary impairment within conceptual knowledge itself to reproduce IW's impaired nonverbal comprehension.

These additional assumptions effectively begin to "soften" the boundary between verbal and non-verbal systems, a dissociation on which these two theories were originally based. The advantage of the unitary hypothesis is that all these data can be explained by a single impairment to an amodal store of conceptual knowledge, which has the greatest effect when form and meaning are arbitrarily related (words) but less impact if there is a systematic connection (pictures). Therefore, although Gogi aphasia may be a good description of the clinical picture seen in many cases of progressive fluent aphasia, if the natural underlying differences between pictures and words are taken into account, this disorder should primarily be considered as resulting from progressive loss of conceptual knowledge—i.e., it is *semantic dementia*.

Manuscript received 28 August 1998

Revised manuscript received 25 May 1999

Revised manuscript accepted 1 July 1999

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