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SEMANTIC DEMENTIA WITH CATEGORY SPECIFICITY: A COMPARATIVE CASE-SERIES STUDY

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Patients with semantic dementia, the temporal variant of frontotemporal dementia, are relevant to both the neuroanatomical and neuropsychological debates in the category-specific literature. These patients present with a selective and progressive semantic deficit consequent on circumscribed atrophy of the inferolateral polar temporal lobes bilaterally, including the inferotemporal gyrus. In this study, a patient KH with a significant advantage for artefacts over living things was compared to five other semantic dementia patients with commensurate levels of semantic impairment. KH demonstrated a consistent category difference in favour of artefacts across all the expressive and receptive semantic tests. This difference was reliable even when familiarity, frequency, and other potential confounding factors were controlled. While KH demonstrated an association between poor knowledge of sensory attributes and a consistently greater impairment on living things than artefacts, the other patients did not. As observed in a number of previous studies, all five of the patients, contrasted to KH, exhibited an advantage for functional/associative over sensory attributes but without demonstrating the category-specific deficit that the sensory-functional theory (and the locus of their atrophy) might predict.

The results of this and other studies are discussed in relation to four accounts of category specificity: the sensory-functional theory, domain-specific knowledge systems, intercorrelated features, and individual differences.

INTRODUCTION

Since the publication of Warrington and Shallice's (1984) seminal paper on the topic, more than 100 patients with category-specific semantic impairment have been described in the literature, predominantly in the form of single-case studies. The term "category specificity" is actually something of a misnomer, as no patient has been reported with an entirely selective impairment for one domain of

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knowledge. We will, however, continue to use this term as it is so solidly established in the literature. The majority of these cases have *relatively* spared performance for nonliving or man-made objects but significantly poorer scores on the same tests when contrasted with living or animate kinds. This pattern is traditionally associated with patients who have suffered from herpes simplex virus encephalitis (HSVE: e.g., Borgo & Shallice, 2001; Gainotti & Silveri, 1996; Sartori & Job, 1988; Warrington & Shallice, 1984) although it has also been reported after head injury (e.g., Farah, Hammond, Mehta, & Ratcliff, 1989; Laiacona, Barbarotto, & Capitani, 1993), cerebrovascular accidents (CVA: e.g., Caramazza & Shelton, 1998; Forde, Francis, Riddoch, Rumiati, & Humphreys, 1997), and dementia of Alzheimer's type (DAT: e.g., Garrard, Patterson, Watson, & Hodges, 1998; Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997). The opposite dissociation, relatively better performance for living than nonliving kinds, has been reported in only a handful of studies, most often as a consequence of CVA (Hillis & Caramazza, 1991; Sacchett & Humphreys, 1992; Warrington & McCarthy, 1987) in addition to a single patient with progressive atrophy of the left temporal and inferior parietal lobes (Silveri, Gainotti, Perani, Capelletti, Carbone, & Fazio, 1997) and occasionally in patients with DAT (Garrard et al., 1998; Gonnerman et al., 1997). The purpose of the present study was to investigate the relationship between category-specific semantic impairments and semantic dementia. Patients with semantic dementia are relevant to two key themes in the category-specific literature: (1) the sensory-functional theory, and (2) critical neuroanatomical regions. Each of these topics is briefly reviewed below.

The sensory-functional theory

Although the literature contains many different cognitive and neuroanatomical accounts of category-specific differences (for recent reviews of the neuropsychological and functional neuroimaging literature, see Caramazza & Shelton, 1998; Devlin et al., 2002b; Humphreys & Forde, 2001; Lambon Ralph, Howard, Nightingale, & Ellis, 1998b), the sensory-functional theory is still, perhaps, the most dominant and influential. Warrington and Shallice (1984) were the first to suggest that man-made objects are primarily differentiated by their functional properties whereas animals are distinguished on the basis of their visual appearance. As a consequence, successful differentiation of one exemplar from another for man-made items should require preserved knowledge of functional features whereas the same process for animate kinds would depend on intact perceptual information. If brain damage disrupts perceptual knowledge, then exemplars of living categories should tend to suffer more; if there is degraded functional knowledge, then the opposite dissociation should result. Warrington and Shallice suggested that a division along perceptual/functional lines was preferable to an explanation based on a genuine category basis for these phenomena, because the former account provided an explanation for the fate of concepts that tend not to follow the living/nonliving distinction. For instance, Warrington and Shallice noted that their patients with relatively poor knowledge of animals were also impaired with respect to types of cloth and precious stone (which have only one generic function and are differentiated primarily by colour or texture) but not with respect to body parts (which have very different functions).

The sensory-functional theory has been taken up by a number of other researchers. Farah and McClelland (1991) described a computational model of semantic memory in which living and nonliving items were coded across differing numbers of visual or functional units. They demonstrated that category-specific deficits emerged after selective "lesions" to either the visual or functional units, in line with Warrington and Shallice's original hypothesis. The model was able to explain why there are no truly selective category-specific deficits by suggesting that both living and nonliving concepts rely on the integrity of both perceptual and functional features, the difference being one of degree. The model also predicted and demonstrated that impoverished perceptual knowledge can be accompanied by a mild deficit for functional features: The interactive nature of the semantic system means that with sufficient damage to the visual semantic units, there is insufficient "critical mass" for the remaining functional semantic units to operate normally. Other studies have supported the sensory-functional theory with the observation that some patients impaired for living categories tend to exhibit poor knowledge about visual but not functional/associative properties of items (e.g., De Renzi & Lucchelli, 1994). In other words there is an interaction between category and attribute type resulting in relatively poor performance on tasks tapping visual knowledge about animate objects. The patient reported by Gainotti and Silveri (1996), for example, when tested on naming to definition, was significantly less likely to provide the appropriate label to a living thing than to a manmade object when the verbal definition stressed perceptual attributes. If the definitions stressed functional information, there was no significant difference between categories—the patient was equally anomic for the animate and inanimate kinds (it should, perhaps, be noted here that these results have been criticised on methodological grounds in that the living and nonliving concepts were not matched for familiarity: Caramazza & Shelton, 1998). In a thorough analysis of patient SRB, Forde et al. (1997) gathered evidence favouring the hypothesis that SRB was impaired on any task that required fine perceptual differentiation. They showed that in addition to exhibiting a category-specific deficit for living things, SRB was also impaired when required to name faces and subordinate categories such as types of car. When asked to put names to definitions containing either functional-associative or visual-perceptual information, SRB was only impaired for the latter type.

Despite these forms of support for the sensory-functional theory, at least seven recent studies have reported patients with a living things deficit without the predicted differential impairment of perceptual knowledge (Caramazza & Shelton, 1998; Funnell & De Mornay Davies, 1996; Laiacona, Barbarotto, & Capitani, 1993; Lambon Ralph et al., 1998b; Moss, Tyler, Durrant-Peatfield, & Bunn, 1998; Samson, De Wilde, & Pillon, 1998; Sheridan & Humphreys, 1993). Perhaps the most memorable of these, because of the historical irony, is a reassessment of patient JBR, originally reported by Warrington and Shallice (1984). Funnell and De Mornay Davies replicated JBR's relatively poor performance for living things even with improved balance of confounding psycholinguistic factors. They found, however, that JBR performed equally well for visual and associative knowledge on a semantic feature questionnaire.

The nature of conceptual impairment in semantic dementia is germane to any potential link between poor perceptual knowledge and category-specific deficits for living things. Patients with semantic dementia (SD) suffer from a progressive deterioration of knowledge about the meanings of words, objects, and concepts (Hodges, Patterson, Oxbury, & Funnell, 1992; Snowden, Goulding, & Neary, 1989). The semantic deficit applies to all modalities of input and output and is accompanied by a profound anomia (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000; Lambon Ralph, McClelland, Patterson, Galton, & Hodges, 2001; Snowden, Neary, & Mann, 1996b). These patients are particularly relevant to the category-specific debate because there is accumulating evidence that their semantic deficit is characterised by relatively poor knowledge of perceptual relative to functional/associative information. Patient TOB with SD (McCarthy & Warrington, 1988; Parkin, 1993), for example, produced definitions of objects that contained considerable functional content with little sensory information; and detailed analyses of word and picture definitions provided by nine other SD patients have confirmed this finding (Lambon Ralph, Graham, Patterson, & Hodges, 1999). Cardebat, Demonet, Celsis, and Puel (1996) reported that their SD patient was able to produce some semantic features regarding function but was unable to draw either animals or objects. Patient DM (Breedin, Saffran, & Coslett, 1994b; Srinivas, Breedin, Coslett, & Saffran, 1997) exhibited a relative preservation of functional over perceptual attributes and a similar dissociation has been shown for patient NV (Basso, Capitani, & Laiacona, 1988). This pattern has been demonstrated not only in verbal output tasks such as definition but also in receptive tasks such as definition-to-word matching and semantic priming (Lambon

Ralph et al., 1998b; Moss, Tyler, Hodges, & Patterson, 1995; Tyler & Moss, 1998).

The problem for the sensory-functional theory is that there is rather little evidence to suggest that this poor visual knowledge in SD leads to category-specific effects. The single-case study by Cardebat et al. (1996) did report a category effect both in naming and word–picture matching but it is unclear if the items were matched for any of the relevant cognitive and psycholinguistic variables. In a group study of nine patients, Hodges, Garrard, and Patterson (1998) obtained a significant category effect in word-to-picture matching (with items balanced for familiarity only) but not in naming. TOB (McCarthy & Warrington, 1988) was reported to have a category effect in verbal definition, and NV (Basso et al., 1988) for verbal comprehension and naming, although in both papers the items were controlled for frequency alone. TOB's naming was assessed by Parkin (1993), who found no category effect when the stimuli were controlled for frequency and familiarity. Breedin et al. (Breedin, Martin, & Saffran, 1994a; Breedin et al., 1994b) reported a significant advantage in DM's comprehension for tools over animals with items matched for frequency. A closer look at the data reveals, however, that DM was impaired on many other man-made categories (e.g., vehicles) and he only exhibited the effect in two out of the three administrations. In addition, on the visual vs. associative attribute test referred to above (which was matched for frequency and familiarity), DM showed a significant difference between attribute types but no difference between living and nonliving categories. In an analysis of the factors that predict naming accuracy in semantic dementia, Lambon Ralph, Graham, Ellis, and Hodges (1998a) found consistent effects of frequency, familiarity, and age of acquisition across the nine patients and for the group as a whole. Only one out of the nine cases, however, demonstrated a significant effect of category over and above the influence of the other variables.

The most convincing report of a category-specific deficit in a case of semantic dementia to date is patient MF studied by Barbarotto, Capitani, Spinnler, and Trivelli (1995). In word-to-picture matching, naming, and answering semantic attribute questions, MF exhibited significantly poorer performance for living categories even when other factors were accounted for, including familiarity, frequency, and item difficulty. In fact for the first two testing sessions in the longitudinal study, MF's scores for the nonliving categories remained in the normal range (i.e., there was a classical dissociation between the two sets). His drawing from memory also indicated a strong category effect. Even this dramatic effect, however, is problematic for the sensory-functional theory because, unlike most other semantic dementia patients, MF failed to show a significant difference between perceptual and associative knowledge on the semantic feature questionnaire.

Critical neuroanatomical regions

Category-specific deficits for living things tend to be associated with temporal lesions typically involving medial and inferior temporal areas (Gainotti & Silveri, 1996; Gainotti, Silveri, Daniele, & Giustolisi, 1995; Saffran & Schwartz, 1994), although there are some notable exceptions (e.g., Caramazza & Shelton, 1998). The majority of deficits affecting man-made items in particular co-occur with lesions to frontoparietal regions (Breedin et al., 1994a; Garrard et al., 1998; Hillis, Rapp, Romani, & Caramazza, 1990; Sacchett & Humphreys, 1992; Warrington & McCarthy, 1983), although sometimes with temporal involvement as well (Silveri et al., 1997; Warrington & McCarthy, 1987, 1994) or occasionally just with temporal atrophy (Hillis & Caramazza, 1991; Tippett, Glosser, & Farah, 1996). Although it is imperative to treat extrapolations from neuroanatomical nonhuman primate data with great caution (Gloor, 1997), these neural substrates are of particular interest because they coincide with the ventral and dorsal visual pathways identified in studies of monkeys (Ungerleider & Mishkin, 1982). This opens up the intriguing possibility of linking neuroanatomy with a cognitive model in the form of the sensory-functional theory: A lesion to the inferior temporal lobe should lead to impaired high-level visual processing and, in turn, to relatively poor performance for animate kinds.

Patients with semantic dementia are also relevant to this aspect of the category-specific literature. The disorder is associated with progressive atrophy of the anterior and inferior temporal lobes bilaterally (Hodges et al., 1992; Mummery, Patterson, Price, Ashburner, Frackowiak, & Hodges, 2000). As noted above, this pattern of atrophy is associated with relatively greater degradation of sensory relative to functional-associative knowledge, but with sparse evidence that this leads, in turn, to a category-specific pattern for living things.

In addition to highlighting the potential importance of the inferior temporal structures, recent neuroanatomical reviews have noted that many of the published category-specific cases for living things have had damage to medial as well as neocortical temporal areas (Gainotti et al., 1995). Likewise a recent meta-analysis of seven PET studies of word retrieval and semantic decision tasks found evidence for activation of bilateral medial temporal poles (Devlin et al., 2002a). Two possibilities arise, therefore: (1) that it is the medial temporal region specifically that is the critical area for this category-specific pattern, or (2) that there is a critical combination of medial and inferolateral damage that leads to poor knowledge for living things. Although recent neuroanatomical investigations have in fact uncovered atrophy to the medial temporal area in patients with semantic dementia (Galton et al., 2001), the balance of atrophy is weighted towards the inferolateral regions (Hodges, 2001). Such a pattern is the reverse of that found in Alzheimer's disease, in which atrophy is most pronounced in the medial temporal lobe (Galton et al., 2001). There are some hints in the current semantic dementia literature that medial areas might be critical to deficits for living things (Garrard, Lambon Ralph, & Hodges, 2002). As noted above, patients with semantic dementia generally have more prominent lateral than medial temporal lobe damage and tend not to have a category-specific semantic impairment. The one case with a clear category effect is different (MF: Barbarotto et al., 1995). MF's temporal lobe atrophy involved medial structures including the hippocampus and parahippocampal gyrus to a much greater extent than that normally seen in semantic dementia. It is also worth noting that MF had greater atrophy in the right than the left temporal lobe. Although recent studies have highlighted bilateral involvement in all but the mildest cases (Mummery et al., 2000), the atrophy is typically asymmetrical and tends to affect the left side more often than the right. The laterality of temporal lobe atrophy and its relationship with category-specific impairments is investigated further in this study.

In this paper, we present case-series data of six patients with semantic dementia. The study was prompted by clinical neuropsychological data that had highlighted an emerging category-specific pattern in one of the cases (patient KH). Assessed three times over a period of 1 year from first presentation, KH's performance on a 64-item naming test remained relatively constant for the 32 man-made items (session 1: 91%; session 2: 91%; session 3: 81%) but dropped steadily for the 32 living items (session 1: 75%; session 2: 63%; session 3: 50%). The same pattern was found for the identical items in a word–picture matching test—man-made (session 1: 100%; session 2: 100%; session 3: 97%) vs. living (session 1: 94%; session 2: 81%; session 3: 63%). At the third testing round, KH was assessed in more detail along with five other patients with mild-to-moderate semantic impairment. This allowed for a direct neuropsychological comparison between semantically impaired patients, with the same aetiology, who varied on whether or not they demonstrated a clear category-specific deficit. Given that patients with semantic dementia are typically homogeneous with respect to both neuroanatomical and neuropsychological profiles, the within-group comparison might provide a revealing method of testing various assumptions regarding category-specific deficits.

STUDY

Patients

The six patients were identified through the Memory and Cognitive Disorders Clinic at Addenbrooke's Hospital, Cambridge, UK, where they were seen by a senior neurologist (JRH), a senior psychiatrist, and a clinical neuropsychologist. In addition to clinical assessment, all patients were given a number of standard psychiatric rating scales to exclude major functional disorders such as depression and schizophrenia. They all underwent MRI scanning together with the usual battery of screening blood tests to exclude treatable causes of dementia.

All six patients fulfilled previously proposed neuropsychological and neuroanatomical criteria for semantic dementia (Hodges, 2001; Hodges et al., 1992; Snowden, Griffiths, & Neary, 1996a): progressive loss of vocabulary affecting expressive and receptive language plus impairments on nonverbal tests of semantic knowledge in the context of relative preservation of phonology, syntax, visuospatial skills, and day-to-day memory. As noted above, longitudinal neuropsychological assessment had revealed an emerging category-specific difference in KH's performance on word–picture matching and picture naming. The five other patients with semantic dementia were selected using both neuropsychological and neuroanatomical criteria; their mild-to-moderate levels of semantic impairment and anomia were roughly commensurate with those for KH. It was important to exclude very severely anomic cases because a number of the planned assessments relevant to the category-specific theories require verbal responses (e.g., picture naming and the production of definitions). In terms of neuroanatomical factors, KH presented with bilateral atrophy with greater damage in the right than the left temporal lobe. This right-sided distribution tends to be less common clinically, but we were able to include one other patient with right-sided atrophy (patient CS). The remaining four cases either had atrophy largely limited to the left temporal lobe (patient AN) or bilateral involvement with a left-sided distribution (patients MA, AT, and SL).

Background neuropsychology

Background neuropsychological results are shown in Table 1. This and all subsequent tables order the patients in the following way. For ease of comparison, KH is always placed last and the remaining five patients are ordered left to right in terms of the severity of their semantic impairment (as measured by their naming and word–picture matching scores—see Table 2). At this time, patient AN was at the very early stages of semantic dementia, such that his mild semantic impairment did not lead to an impairment on all of the semantic assessments included here. His results are included in this study in order to span a range of semantic severity. On the Mini-Mental State Examination (MMSE: Folstein, Folstein, & McHugh, 1975) two patients achieved excellent scores (AN and MA) while the rest fell below normal control performance. Typically patients with semantic dementia pass the orientation questions but fail at those requiring expressive and receptive language skills. Like other SD patients reported in the literature, the four cases who were tested on the Raven's Coloured Progressive Matrices—a test of nonverbal problem solving (Raven, 1962)—performed very well. With the exception of CS, the remaining five patients achieved normal scores on digit span (on both forward and backward subtests from the Weschler Memory Scale-Revised: Wechsler, 1987). On other measures of recall and recognition memory (the Rey-Osterrieth figure delayed copy: Osterrieth, 1944; the Recognition Memory Test: Warrington, 1984), CS again performed poorly. AN, MA, and SL produced scores within the normal range. KH's and AT's recognition scores were relatively weak. CS's immediate copy of the Rey figure was also impaired. On the perceptual and spatial subtests (VOSP: Warrington & James, 1991), all patients demonstrated the typical pattern of good scores with the exception of silhouette identification, which requires access to semantic memory.

Table 1. *Background neuropsychology*

Test	*Subtest*	*Max*	*Patient* *AN*[a] *63 yrs*	 *CS*[b] *64 yrs*	 *MA*[a] *63 yrs*	 *AT*[a] *65 yrs*	 *SL*[a] *52 yrs*	 *KH*[b] *59 yrs*	*Controls*[c]
MMSE		30	30	15	29	25	24	22	28.8 (0.5)
RCPM		%tiles	36	NT	75th	90–95th	90–95th	95th	
Digit span	Forward		7	4	6	8	5	6	6.8 (0.9)
	Backward		7	2	3	5	4	5	4.7 (1.2)
RMT	Word	%tiles	50–75	<5	50	25	<25	<5	
	Faces	%tiles	75–95	<5	25	<5	50–75	<5	
Rey Figure	Immediate	36	36	21	36	36	30	29.5	34.0 (2.9)
	Delayed	36	27	0	6.5	24	14	12.5	15.2 (7.4)
VOSP	Letters	20	19	18	19	20	20	19	16–20
	Silhouettes	30	17	9	7	7	NT	NT	15–30
	Object decision	20	20	15	16	19	13	18	14–20
	Dot count	10	10	10	10	10	9	10	8–10
	Position discrimination	20	20	19	20	20	NT	NT	18-20
	Number location	10	9	9	10	9	NT	NT	7–10
	Cube analysis	10	10	8	10	10	10	9	6–10

MMSE: Mini-Mental State Examination. RCPM: Raven's Coloured Progressive Matrices. RMT: Recognition Memory Test. VOSP: Visual Object and Space Perception Battery. NT: Not tested.

[a] Left greater than right temporal lobe atrophy.

[b] Right greater than left temporal lobe damage.

[c] Given as Mean (*SD*) or range.

Assessments of semantic memory

The performance of the patients on a set of semantic and name production tasks is shown in Table 2. On the Pyramids and Palm Trees test of associative semantics (Howard & Patterson, 1992), all patients' scores fell below the control range [pictures: mean = 51.1, *SD* = 1.1; words: mean = 51.2, *SD* = 1.4]. Their pronounced anomia gave rise to poor letter and category fluency scores [data of 38 age- and education-matched controls: letter fluency: mean = 44.2, *SD* = 11.2; category fluency for four animal categories: mean = 60.3, *SD* = 12.6; for four man-made categories: mean = 54.8, *SD* = 10.3]. As a group, the patients showed no significant difference in the number of exemplars produced for the living and manmade domains. In the 64-item naming and word–picture matching tests, both CS and KH exhibited a statistically reliable difference between living and man-made items. As a group the patients tended to perform slightly better on the man-made items, although the small differences only reached borderline significance in word–picture matching (this replicates the pattern found previously by Hodges et al., 1998).

The 64-item semantic battery was designed to form part of a general neuropsychological assessment for all patients presenting to the Memory and Cognitive Disorders clinic. By using this same battery on all patients, both cross-sectionally and longitudinally, clinical and theoretical insights about the status and nature of conceptual knowledge have been gleaned (e.g., Bozeat et al., 2000; Garrard, Lambon Ralph, Watson, Powis, Patterson, & Hodges, 2001b; Hodges & Patterson, 1995). Indeed, it was the use of this battery that highlighted KH's emerging category-specific deficit. One drawback, however, is that the full subsets of 32 living and 32 man-made items are not matched for concept familiarity. Many previous studies have demonstrated that the accuracy of patients with semantic dementia is influenced by familiarity (e.g., Bozeat et al., 2000; Lambon Ralph et al., 1998a), and this variable is known to vary

Table 2. *Background semantic and naming assessments*

			Patient						
Test	*Subtest*	*Max*	*AN*	*CS*	*MA*	*AT*	*SL*	*KH*	*Mean*
PPT	Pictures	52	NT	41	41	47	44	42	–
	Words	52	NT	39	42	45	38	40	–
Fluency	Letters (FAS)	N/A	40	14	9	20	30	13	–
	Man-made[a]	N/A	34	25	8	18	7	14	17.7
	Living[a]	N/A	47	13	7	14	12	8	16.8
									t = 0.23
									p = .83
64 naming	Man-made	32	32	28	5	12	7	26	18.3
	Living	32	32	19	8	5	11	16	15.2
	χ^2		–	5.13	0.39	2.88	0.70	5.61	*t* = 1.24
	p		–	***.02***	.53	.09	.40	***.02***	*p* = .27
64 word-picture matching	Man-made	32	32	29	30	30	24	31	29.3
	Living	32	32	22	27	27	24	20	25.3
	χ^2		–	3.48	0.64	0.64	0	9.65	*t* = 2.28
	p		–	.06	.42	.42	1	***.002***	*p* = .07
Controlled set naming	Man-made	30	28	15	7	11	10	24	15.8
	Living	30	30	14	17	6	13	17	16.2
	χ^2		0.52	0.07	6.94	2.05	0.64	3.77	*t* = 0.13
	p		n.s.	n.s.	***.008***	.15	n.s.	***.05***	n.s.

[a] 4 categories.

across living and nonliving domains (on average animals are less familiar than artefacts: Funnell & Sheridan, 1992). We administered, therefore, three additional assessments designed to test for category differences over and above the influence of familiarity and other potential confounding factors. The first contrasts 30 animal–man-made pairs that are closely matched on a variety of psycholinguistic factors including familiarity, frequency, length, and imageability (taken from Lambon Ralph et al., 1998b). On this naming test (shown in the bottom row of Table 2), CS's previous category difference disappeared while KH's better naming for man-made things remained and was statistically reliable. The other patients continued to show no difference between the two domains except for patient MA, who was significantly more accurate for the living things. Overall the patients' performance for this test was very similar for living and nonliving domains.

In addition to the controlled naming test, we also administered naming and word–picture matching tests based on the full Snodgrass and Vanderwart picture set (1980). For picture naming, the patients were simply asked to provide the name of each item. In the word–picture matching test, the name of each picture was spoken by the experimenter and the patient was required to point to the correct item from a choice of four within-category exemplars. Given the large number of pictures, it is possible to test for an effect of domain whilst controlling for a series of other possible confounding factors (logistic regression for individual data and multiple regression for overall, by-item data). Values for rated familiarity, objective age-of-acquisition (AoA), rated imageability, name agreement, phoneme length, rated visual complexity, and Celex frequency are available for 221 of the 260 pictures (taken from Morrison, Chappell, & Ellis, 1997). The patients' raw scores on the two tests for this subset of items and the results of the regression analyses are shown in Tables 3a and 3b.

Table 3a shows the results from the word–picture matching test. In terms of raw scores, three patients were significantly less accurate for living than nonliving items. CS and MA exhibited a 10% difference between the two domains while a greater differential was observed in KH (18%). A by-subjects *t*-test with KH included reached borderline significance, with better performance overall for the man-made domain. With KH excluded, the reduced domain difference failed to reach any level of statistical significance. The lower half of Table 3a lists the *p* values obtained for each patient's logistic regression analysis plus two multiple regressions based on the by-items data. The multiple regression was repeated with KH included and excluded to test whether the overall result was changed by his

Table 3a. *Analysis of factors affecting word-to-picture matching*

		Patient						*Average with KH*	*Average without KH*
	N	*AN*	*CS*	*MA*	*AT*	*SL*	*KH*		
Domain									
Man-made	138	136 (99%)	135 (98%)	127 (92%)	134 (97%)	121 (88%)	131 (95%)	94.8%	94.8%
Living	83	82 (99%)	74 (89%)	67 (81%)	78 (94%)	75 (90%)	64 (77%)	88.3%	90.6%
χ^2		0	5.99	6.18	0.62	0.37	15.9	t = 2.11	t = 1.67
p		n.s.	.01	.01	n.s.	n.s.	<.001	p = .09	n.s.
Regression factor									
Domain		n.s.	n.s.	n.s.	n.s.	n.s.	.001	.007	n.s.
Familiarity		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Objective AoA		n.s.	n.s.	.05	n.s.	n.s.	n.s.	<.001	<.001
Imageability		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Name agreement		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Phoneme length		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Visual complexity		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Celex frequency		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 3b. *Analysis of factors affecting naming*

		Patient						*Average with KH*	*Average without KH*
	N	*AN*	*CS*	*MA*	*AT*	*SL*	*KH*		
Domain									
Man-made	138	127 (94%)	93 (67%)	66 (48%)	69 (50%)	52 (38%)	102 (74%)	61.8%	59.4%
Living	83	77 (93%)	47 (57%)	40 (48%)	22 (27%)	31 (37%)	39 (47%)	51.5%	52.4%
χ^2		0.15	2.59	0	11.8	0	16.3	t = 2.11	t = 1.60
p		n.s.	n.s.	n.s.	.001	n.s.	<.001	p = .09	n.s.
Regression factor									
Domain		n.s.	n.s.	n.s.	.03	n.s.	<.001	n.s.	n.s.
Familiarity		n.s.	.008	.001	<.001	<.001	<.001	<.001	<.001
Objective AoA		.002	.001	.001	n.s.	.001	.003	<.001	<.001
Imageability		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	.009	.02
Name agreement		n.s.	n.s.	n.s.	n.s.	.01	n.s.	n.s.	n.s.
Phoneme length		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	.05[a]
Visual complexity		n.s.	.02	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Celex frequency		n.s.	n.s.	n.s.	.001	n.s.	n.s.	n.s.	n.s.

[a] Better performance for longer than for shorter words.

data specifically. Once other confounding variables were controlled in this way, neither CS nor MA exhibited a significant independent effect of domain. Likewise, no domain effect emerged for any of the cases who had failed to show a domain effect in their raw data (AN, AT, and SL). In contrast, even with these other factors controlled, the effect of domain remained significant for KH, with no other variables reaching significance. In the overall by-items regression analysis with KH included, both domain and age-of-acquisition were significant. While the effect of AoA remained even if KH was excluded, domain became non-significant. This suggests that it was KH's data, specifically, which gave rise to the domain effect in the overall data.

The analyses of the naming data are summarised in Table 3b. In terms of raw scores only AT (who had not shown a domain effect in word–picture matching) and KH demonstrated a significant domain difference. Again the overall by-subjects *t*-test only reached borderline significance if KH's data were included. In the regression analyses most of the patients were affected by familiarity and object AoA (replicating the results found previously for a different group of semantic dementia patients: Lambon Ralph et al., 1998a). In addition, the domain effect remained significant for AT and KH individually, though in the overall by-items regression, only effects of familiarity, AoA, and imageability were found.

Assessment of attribute knowledge

The patients' knowledge of specific types of semantic attribute was assessed using three tasks. The first two were naming to description and description-to-picture matching. In both tests, patients were presented with a definition for each of the 64 items used in the basic naming and word–picture matching tasks described above. For each item two definitions were prepared, one that emphasised sensory information and another that utilised functional-associative attributes. In naming to description, the definition was simply read by the experimenter and the patient was required to give the name of the concept described. The matching version of this task was prepared in an attempt to circumvent any floor effects that might have arisen due to the pronounced anomia of patients with semantic dementia. In this task, after listening to the description, instead of attempting to name it, the patient was asked to pick the correct picture from an array of within-category exemplars (the same arrays as those used in the 64 word–picture matching test).

The results for naming to description and description-to-picture matching are shown in Tables 4a and 4b. In each table, the upper half shows the patients' accuracy split by attribute type while the lower half divides their data by domain. When split by attribute type a clear pattern emerged for the patients—all were numerically better when presented with associative-functional rather than sensory definitions. For the naming task, this difference was statistically significant for four of the six cases (MA, AT, SL, and KH) and was reliable overall in the by-subjects analysis. Despite their relatively poor ability to name in response to the sensory definitions, it was only KH who demonstrated a clear and significant domain difference. The overall by-subject analysis was also nonsignificant. Although the patients were substantially more accurate with the matching version of this task, the same basic pattern emerged. Despite being presented with pictures of the target item, all patients were numerically worse at the sensory definitions. Though the differences were small, the effect was reliable for SL individually, and in the overall by-subjects analysis. Again there was no clear pattern when the data were split by domain. Only KH exhibited a clear domain difference and the overall by-subjects analysis was nonsignificant.

The third assessment elicited verbal definitions to test the patients' attribute knowledge. The 6 patients were compared with 10 age-matched controls. The subjects were asked to give definitions for each of the 64 concepts included in the various semantic assessments described above. Specifically, the participants were given the spoken name of a concept and were asked to provide as much information as they could about that item. General prompts (e.g., "What does it look like?", "What does it do?", "Where would you find it?", "What

Table 4a. *Naming to description*

		Patient						
		AN	*CS*	*MA*	*AT*	*SL*	*KH*	*Mean*
Definition type								
Functional	/64	48	21	37	18	24	37	30.8
Sensory	/64	42	15	27	8	13	16	20.2
χ^2		1.35	1.39	3.13	4.83	3.87	14.2	t = 4.75
p		n.s.	n.s.	.08	.03	.05	<.001	.005
Domain								
Nonliving	/64	41	21	35	12	16	33	26.3
Living	/64	49	15	29	14	21	20	24.6
χ^2		2.4	1.4	1.13	0.19	0.95	5.4	t = 0.5
p		n.s.	n.s.	n.s.	n.s.	n.s.	.02	n.s.

Table 4b. *Description-to-picture matching*

		Patient						
		AN	*CS*	*MA*	*AT*	*SL*	*KH*	*Mean*
Definition type								
Functional	/64	62	48	47	55	24	49	47.5
Sensory	/64	61	41	38	53	13	43	41.5
χ^2		0	1.81	2.84	0.24	4.6	1.39	t = 3.77
p		n.s.	n.s.	n.s.	n.s.	.03	n.s.	.01
Domain								
Nonliving	/64	63	46	42	56	16	53	46
Living	/64	60	43	43	52	21	39	43
χ^2		0.83	0.33	0.04	0.95	0.95	7.58	t = 1.16
p		n.s.	n.s.	n.s.	n.s.	n.s.	.006	n.s.

else do you know about it?") were used repeatedly with patients and controls to encourage information regarding each object's perceptual features, function, and other encyclopaedic-associative facts. Definitions were collected over two or three sessions for the patients because the process was very time-consuming and arduous for them. The definition naming and matching tests, reported above, were administered during other testing sessions to minimise any likelihood of priming or cueing effects. The elicited definitions were broken down into individual features and each was classified into five main types: sensory, functional, encyclopaedic, superordinate, and errors (using the same criteria as Garrard, Lambon Ralph, Hodges, & Patterson, 2001a). Classifications were made by one scorer (JD) and then double-checked (by MALR). The upper half of Table 5 shows the number of each type of feature produced by each patient individually, the patient and control means plus the performance of the worst control (i.e., the least information produced by a control for that feature type). The results for the patients were consistent across individuals and replicated the pattern found in the naming to description task—the patients' definitions were generally impoverished in comparison to the controls' and were dominated by functional and encyclopaedic attributes. Like the controls, the patients produced a relatively low rate of superordinate classifications and incorrect features. As in previous analyses of definitions produced by patients with semantic dementia, there is a striking contrast between the proportions of sensory and functional information given. In this study the ratio of sensory to functional attributes in the patients' definitions (35%: 41%) was the reverse of that

Table 5. *Analysis of the rate and type of attributes produced in verbal definition*

Attribute type	*AN*	*CS*	*MA*	*AT*	*SL*	*KH*	***Patient mean***	***Control mean***	*Worst control*
	Number of attributes given (Percentage of own total production)								
Sensory	158 (40%)	39 (21%)	53 (37%)	91 (35%)	59 (34%)	103 (38%)	**83.8 (35%)**	**512.5 (57%)**	351 (55%)
Functional	154 (39%)	81 (45%)	62 (44%)	113 (43%)	75 (43%)	106 (39%)	**98.5 (41%)**	**196.8 (22%)**	152 (24%)
Encyclopaedic	68 (17%)	39 (21%)	26 (18%)	35 (13%)	20 (12%)	36 (13%)	**37.3 (15%)**	**125 (14%)**	91 (14%)
Superordinate	44 (11%)	23 (13%)	1 (1%)	18 (7%)	19 (11%)	13 (5%)	**19.7 (8%)**	**62.7 (7%)**	44 (7%)
Errors	0 (0%)	0 (0%)	0 (0%)	5 (2%)	0 (0%)	11 (4%)	**2.7 (1%)**	**0 (0%)**	0 (0%)
Total	424	182	142	262	173	269	**242**	**897**	638
	Percentage of control mean performance								
Sensory	31%	8%	10%	18%	12%	20%	**16%**		
Functional	78%	41%	32%	57%	38%	54%	**50%**		
Encyclopaedic	54%	31%	21%	28%	16%	29%	**30%**		
Superordinate	70%	38%	20%	29%	30%	21%	**20%**		
Total	47%	20%	16%	29%	19%	30%	**27%**		

found for the control subjects (57%: 22%). A 2 (subject group) × 2 (feature type: sensory vs. functional) ANOVA confirmed that this crossover interaction was significant, $F(1, 14) = 90.8, p < .001$. Post-hoc t-tests revealed that the feature type difference for controls was significant and for patients it approached significant albeit in the opposite direction [semantic dementia: $t_{(5)} = 2.2$, $p = .08$; controls: $t(9) = -12.1, p < .001$].

The lower half of Table 5 summarises the patients' definitions in a different way. The number of attributes of each type is expressed as a proportion of the mean control performance. This confirms two key aspects of the patients' definitions. First, the patients produced a much smaller number of features than the control subjects. Overall, the patients gave only 27% of the number of features that control subjects did. The rate was low even for the mildest SD patient (AN: 47%). The average rate of sensory features was lowest (16%). The rate of encyclopaedic and superordinate attributes dropped moderately (encyclopaedic: 30%; superordinate: 31%). In contrast, although the rate of functional features reduced considerably, the proportion (50%) was twice that of the other attribute types.

To finish this section, we will consider another control dataset against which the patients' performance can be compared. A growing number of studies, using a variety of verbal and nonverbal tasks, have found that semantic dementia patients are relatively more likely to produce attributes shared by many concepts (e.g., has legs, moves, is found in the UK) than features specific to a few (e.g., has long ears, burrows, was introduced into the UK by the Romans: Hodges, Graham, & Patterson, 1995). This pattern is true of the definitions collected for these and other patients with semantic dementia. It is important, therefore, to rule out the possibility that the change in the sensory:functional ratio is not merely an artefact of the patients' definitions becoming increasingly dominated by shared attributes. We can do this by comparing the present data against the detailed analyses of normal feature-listing performance provided by Garrard and colleagues (2001a). In that study, Garrard et al. split the attributes both by type and by their relative distinctiveness: i.e., into those that were shared by at least half of the concepts within a category versus those that were true for only a small number of exemplars (less than half the concepts in a category). One possible analysis of the semantic dementia data is, therefore, to compare the patients' rate of production not against the total number of features produced by control subjects but instead against the rate of relatively shared features. If the patients' poor knowledge of sensory features is simply an artefact of their definitions becoming increasingly dominated by the shared features, then the shared attributes produced by control subjects should mimic the patient's results. Even for these features, however, Garrard et al.'s normative data show that the rate of shared sensory features for the 64 concepts was twice that found for shared functional and encyclopaedic facts (see Figure 6 in Garrard et al., 2001a). It seems, therefore, that in addition to the general finding that distinctive features are particularly vulnerable in this form of semantic impairment, the loss of conceptual knowledge in patients with semantic dementia is characterised by a relative preservation of functional information.

DISCUSSION

This study investigated the issue of category-specific semantic differences with reference to neuropsychological data of patients with semantic dementia. Six patients with mild to moderate semantic impairment were studied. One of the six (patient KH) had presented an emerging category-specific advantage for man-made over living concepts. A battery of neuropsychological tasks was used to compare KH directly with the other semantic dementia patients and to test various accounts of category-specificity. KH demonstrated a consistent domain difference across all semantic tests both for receptive tasks (word–picture matching and definition-to-picture matching) and expressive tasks (various picture naming tests, and naming to definition). The difference between living and nonliving concepts remained even when other possible confounding factors such as familiarity and frequency were controlled. In contrast, none of the remaining patients exhibited a *consistent* category-specific difference. A patient would occasionally demonstrate a difference on one test that either was removed when confounding variables were controlled or failed to be replicated with another test even of the same type—e.g., on two picture naming tasks. In other aspects, all six patients, including KH, produced homogeneous results. As in previous investigations of factors that affect semantic performance (Bozeat et al., 2000; Funnell, 1995; Lambon Ralph et al., 1998a), each individual and the group as a whole were affected by concept familiarity. In addition, all patients exhibited a relative preservation of functional over sensory features when asked to provide verbal definitions, name to definition, and match definitions to pictures.

Along with one other patient in the literature (patient MF: Barbarotto et al., 1995), KH represents one of the clearest cases of category-specificity in semantic dementia. As we will discuss further below, the combination of semantic dementia and category specificity is something of a rarity. This study aimed to compare KH with a series of other semantic dementia patients and, with this potentially powerful case-series design, to reveal any underlying neuropsychological or neuroanatomical factors that might underpin the category-specific difference. Four factors can be considered. First KH, like MF (Barbarotto et al., 1995), presented with bilateral temporal lobe atrophy with an asymmetric distribution weighted towards greater atrophy of the right temporal lobe. Unlike patient MF, KH had the usual SD pattern of greater atrophy of the inferopolar regions than of the medial temporal lobe. Although the opposite, left-distributed pattern of atrophy tends to be the most common in the clinic (Hodges, 2001; Mummery et al., 2000), the case-series studied here included one other patient with greater right than left temporal lobe damage (CS). There was little evidence for a category effect in CS and thus it seems unlikely that the left–right distribution of temporal lobe atrophy is the critical factor.

A second possibility relates to the severity of the semantic impairment. It is possible that category differences might only arise in patients with a certain degree of semantic impairment (indeed, this is a prediction of those theories that explain category specificity in terms of intercorrelated features, see below). The case-series was selected, however, with the criterion that the patients should be roughly commensurate with KH in terms of semantic severity. Although patient AN was milder than KH, the other four cases produced very similar scores across the range of semantic assessments (see Table 2). It would seem, therefore, that the severity of semantic impairment is not a critical factor in KH's category-specific pattern.

The third factor relates to the possibility that category-specific impairments arise when a semantic impairment combines with some other cognitive deficit. For example, reviews of the category-specific literature have noted that patients often have the combination of semantic impairment and a dense amnesia (e.g., those patients with category-specific deficits in the context of the medial and inferolateral temporal damage observed in HSVE: Gainotti et al., 1995). There is existing evidence that this combination is not critical: Patients with Alzheimer's disease normally have amnesia combined with semantic impairment without a category-specific pattern (also in the context of medial and inferolateral temporal damage: Garrard et al., 1998, 2001b) and patients with category-specific impairments for living things following middle-cerebral artery stroke do not have dense amnesia (e.g., Caramazza & Shelton, 1998; Hillis & Caramazza, 1991). In addition, there is no evidence that KH's semantic impairment was accompanied by any additional neuropsychological impairment that the other SD cases did not also have. For example, although KH's scores on the recognition memory tests were relatively weak (see Table 1), patient CS, unusually for patients with mild SD, had a much more pronounced amnesia than KH but without the category-specific pattern. The other background neuropsychological assessments also failed to highlight any other critical impairment.

The final possibility relates to the pattern of semantic breakdown itself. For example, KH's category-specific impairment might have occurred in the context of a pattern with other unusual semantic characteristics. Our fairly extensive semantic assessment, which included relatively rich sources of data such as verbal definitions, failed to highlight any obvious differences. Just like the other five patients, KH's semantic degradation was characterised by relatively impoverished concepts in which distinctive properties are the most vulnerable and, although significantly reduced too, functional features are less affected than sensory attributes. In summary, KH's neuroanatomical and neuropsychological profile matched the other five semantic dementia patients included in this case-series in all respects save for the fact that, over and above this typical SD profile, KH had some unspecified additional impairment which produced relatively poor performance for living things.

The basis of the sensory-functional theory is that concepts in the living domain are more reliant on sensory features while man-made items are strongly represented in terms of functional attributes. The performance of the patients described here replicates that reported before (Lambon Ralph et al., 1998b, 1999): When SD patients define object concepts, they provide significantly fewer sensory attributes than for functional features. With the exception of patient KH, the remaining five SD patients plus the others reported previously failed to show the predicted disadvantage for living things. The combination of relatively poor sensory knowledge without an emergent category-specific pattern would appear problematic for the sensory-functional theory. There are, however, at least two possible counterarguments that can be considered in the light of the comparative data provided by KH. First, these patients do not have a classical dissociation for functional over sensory attributes—their overall feature knowledge is greatly impoverished relative to normal controls for *all* types of feature. The possibility arises, therefore, that the difference between functional and sensory information is insufficiently large to produce a category difference (Lambon Ralph et al., 1998b, 1999). KH's comparative data would seem to make this counterargument less likely: his performance on the feature-based tasks (naming to definition, definition matching, and verbal definitions) was indistinguishable from the other five patients. If the difference between sensory and functional knowledge was sufficient to produce a category effect in KH, it should have also done so with the other five cases.

The second, related counterargument relates to the strong familiarity-frequency effects observed for comprehension and production in semantic dementia (Funnell, 1995; Lambon Ralph et al., 1998a). Borgo and Shallice (2001) have argued that a previously described patient's poor sensory knowledge in receptive and expressive tasks (patient IW: Lambon Ralph et al., 1998b) might have been due to a potential confound with frequency—if the perceptual terms were relatively low-frequency words. Again KH's comparative data are illuminating here. KH's pattern is compatible with the sensory-functional theory: Poor sensory knowledge is paired with a category-specific deficit for living things. The remaining patients' data could be explained using the Borgo and Shallice hypothesis if psycholinguistic factors such as word frequency artificially suppressed the patients' performance for sensory attributes when, in fact, there was parity between sensory and functional knowledge and thus there should have been no category effect. The two arguments are *not* mutually compatible, however, because the same materials were used for all six patients. This means either that poor sensory knowledge resulted in no emergent category effect in the majority of cases, or else that KH's category effect was not meaningfully related to his relatively poor sensory knowledge. Both results are incongruent with the sensory-functional hypothesis.

The category-specific literature contains a relatively large number of explanations of which the sensory-functional theory is only one. We will conclude this paper by considering three other proposals: domain-specific knowledge systems, intercorrelated features, and individual differences.

Domain-specific knowledge systems are based on the idea that semantic memory is divided into subsystems for each broad domain (animals, vegetation, and artefacts) either through evolutionary pressures (Caramazza & Shelton, 1998) or by the learning process itself (Ritter & Kohonen, 1989). Under these proposals, category-specific deficits really do reflect dissociations between separable, domain-specific neural systems or processes. Under this hypothesis, for the majority of semantic dementia patients, all domains/semantic subsystems are affected equally by the progressive disease. KH, on the other hand, had an uneven distribution of damage to the three domains such that the artefact domain was relatively preserved. The major problem with this approach is that it is little more than a redescription of the data and lacks any form of neuroanatomical or neuropsychological explanatory power (although it does predict that there is no causal relationship between feature type and category knowledge, which is supported by the semantic dementia data). Although Caramazza and Shelton (1998) do not link any of the domain-specific knowledge systems to any particular neural regions, it is implicit in the theory that each domain must be neurally separable from each other in order to produce neuropsychological double dissociations. There is no evidence, however, that KH's temporal lobe atrophy was any different to the other cases included in this series or reported elsewhere. In general, the lack of independent, a priori, neuroanatomical or neuropsychological predictors of which domain should become impaired significantly limits the appeal of domain-specific proposals (more detailed critiques of these theories can be found elsewhere: Borgo & Shallice, 2001; Lambon Ralph et al., 1998b).

Recent studies have tried to explain category specificity in terms of the distribution and effect of intercorrelation between constituent semantic features (Devlin, Gonnerman, Anderson, & Seidenberg, 1998; Gonnerman et al., 1997; McRae & Cree, 2002; Tyler, Moss, Durrant-Peatfield, & Levy, 2000). There are two separate theories based on intercorrelated features, which produce opposite predictions regarding the impact of disease severity. The first theory (Devlin et al., 1998; Gonnerman et al., 1997) notes that the constituent features of living concepts are significantly more intercorrelated than the features for nonliving items (McRae, De Sa, & Seidenberg, 1997). When this pattern is coded within a computational model of semantic memory, a double dissociation can be produced without selective lesioning of one type of attribute over another (which was the basis of Farah and McClelland's model, 1991). Intercorrelated features are relatively robust to mild levels of semantic impairment and, therefore, at this level of damage concepts for living things are better preserved than for nonliving things. At greater degrees of semantic impairment the intercorrelation leads to a catastrophic loss of information underpinning living concepts and in these circumstances the category-specific pattern is reversed (nonliving > living). The second form of these theories highlights a different pattern of intercorrelated features. Moss et al. (1998) and Tyler et al. (2000) argue that for living things the intercorrelated features are also those shared across exemplars within a category (e.g., eyes, ears, sees, hears), whereas for nonliving things there is a subset of form–function intercorrelations that are relatively specific to each exemplar (e.g., saw blade and cutting). The direction of category difference with respect to the severity of the semantic impairment is reversed in this theory: Living concepts suffer initially from not having highly intercorrelated distinctive features but they become relatively preserved at more extreme levels of semantic impairment because they are somewhat protected by their intercorrelated shared features. Although the basis of both theories has been questioned on various grounds including feature norms (Garrard et al., 2001a), computational modelling (Perry, 1999), and neuropsychological data (Garrard et al., 1998, 2001b; Hillis & Caramazza, 1991), the critical prediction for the semantic dementia data presented here is that the direction of the category difference should depend on the degree of the semantic impairment. The patients selected for this study were in the mild–moderate range of semantic impairments. KH, the patient with relatively poor performance for living things, fell into the middle of this group. Neither the milder (e.g., patient AN) nor more severely impaired patients (e.g., patient SL) demonstrated the same pattern as KH. Likewise a previous investigation of factors affecting naming in patients with semantic dementia failed to find category-specific differences in much more severely impaired cases (whilst also controlled for confounding psycholinguistic factors: Lambon Ralph et al., 1998a). Although models of conceptual knowledge based on the statistical co-occurrence of object properties provide important insights about semantic memory in general, the SD patients provide little positive evidence for the intercorrelated feature theories of category differences specifically (see also McRae & Cree, 2002).

The final possibility we shall consider is the influence of individual differences. One of the limitations of single-case methodology is that individual fluctuations in performance are hard to detect and to control. Thus it can be difficult to know when a significant effect in performance (e.g., artefacts better than living) truly reflects a stable characteristic of the underlying cognitive architecture, random fluctuations in test performance, or a premorbid individual difference that alters the functioning of the cognitive process (Lambon Ralph, Moriarty, & Sage, 2002; Plaut, 1997). The case-series approach, including multiple assessments of each task (e.g., several naming tests), suffers less from this drawback because each patient can be compared not only with normal performance but also with the other patients of the same type and even with himself or herself. Fluctuations in test scores leading to Type I statistical errors were observed in this study—occasionally an individual patient would exhibit a difference between the two domains of knowledge on a specific test. It was only KH, however, who demonstrated a consistent pattern across essentially all tests requiring semantic memory. Random fluctuation in test scores does not explain KH's category-specific impairment, therefore; but individual differences could do so.

There is clear evidence for significant individual differences in conceptual knowledge within the normal population. Analyses of control performance have identified individual variation in knowledge for animate, plant, and artefact domains (Funnell & De Mornay Davies, 1996). Male–female differences for knowledge of praxic objects, animals, and edible substances have also been found in psychometrically graded tests (McKenna, 1997). If a person happened to have considerable experience of artefacts, or a lack of experience with animals, then it would not be surprising if a generalised semantic impairment produced differences between living and nonliving domains for that patient. The underlying mechanism for this effect is the same as for the role of familiarity: PDP models clearly demonstrate that frequent presentation during training makes representations more robust to damage (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996). Without some form of independent measure of premorbid individual differences, however, this explanation suffers from the same criticism as that noted above for domain-specific knowledge theories—that it is simply a redescription of the data: Patients with no category difference are assumed to have had equivalent premorbid knowledge of each domain while KH's premorbid knowledge of animals was weak.

An individual differences explanation is made more plausible, at least for semantic dementia, if we consider the prevalence of category-specificity within that disorder. Over the last decade, approximately 40 SD patients, presenting to the Memory and Cognitive Disorders Clinic at Addenbrooke's Hospital, have been given a neuropsychological clinical battery including the 64-item naming and word–picture matching tasks reported here. Of these 40 patients, KH is the only one to have demonstrated a clear difference in favour of artefacts. If we combine the current patients with those reported in three recent papers (Lambon Ralph et al., 1998a, 1998b, 1999), then there are 18 cases who have been assessed in more detail whilst controlling for confounding psycholinguistic factors. KH is once again the only patient to have presented with significant and reliably worse performance for living things. Of course, if there are individual differences then the majority of cases should fall into the middle ground (i.e., show no category effect) while a small number should fall to *both* ends of the distribution. It is important to note, therefore, that while KH was the only case with poorer performance for living things, another 1 of the 18 demonstrated a small but consistent difference in the opposite direction, which persisted over the course of her progressive illness (patient IW: Lambon Ralph & Howard, 2000; Lambon Ralph et al., 1998b).

This proposal begs the obvious question of whether individual differences provide an explanation for category-specific deficits in semantic dementia alone or for other patients as well. It is possible that at least some of the other reported single cases could have arisen from premorbid differences in knowledge. Future case-series or group studies are required to rule out individual differences as a general explanation for category specificity. If a certain category-specific pattern is consistently associated with a certain disease type, underlying distribution of neurological damage, or pattern of cognitive deficits, then an account on the basis of individual differences would not be plausible. In any event, an explanation in terms of individual differences will continue to feel under constrained and unsatisfying unless and until there is some independent basis on which to predict who should fall where in the distribution. At present, however, it remains a leading contender for explaining an otherwise puzzling set of patterns in the domain of category specificity.

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