LOSS OF STORED KNOWLEDGE OF OBJECT STRUCTURE: IMPLICATIONS FOR "CATEGORY-SPECIFIC" DEFICITS

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Following a right-hemisphere lesion, the patient SM had impaired object recognition, with good elementary visual abilities, and could derive information about object structure. He was also impaired on all tasks tapping stored structural knowledge, even when tested in the verbal modality. This suggests that SM has a disorder affecting stored knowledge of object structure, though he remains able to assemble novel structural descriptions. His object recognition ability also appeared significantly worse for non-living things. By contrast, existing models relating to stored knowledge would predict that SM would show greater impairment with living things. We argue that SM's deficit reflects the loss of a type of structural knowledge that relates to the "within-item structural diversity" of items. It is argued that living things show *less* structural variation than objects in the natural world, and might arguably be *easier* to recognise, because the image of the to-be-recognised object would be similar to the stored representation. Hence, a deficit affecting this aspect of stored knowledge would differentially impact upon non-living things. This argument receives confirming independent support from the finding that normal subjects ratings for the within-item structural diversity of visual stimuli are (unlike other "critical" variables) significant predictors of SM's naming performance.

INTRODUCTION

Some patients with deficits in object identification have greater difficulty recognising particular "categories" of object—the simplest (and earliest) suggestion being that such patients had selectively lost the ability to recognise either animate or inanimate objects (e.g. Warrington & Shallice, 1984). Category-specific deficits have received considerable interest because of their implications for models of object recognition and, in particular, the structure of stored knowledge (see Caramazza & Shelton, 1998, for review). Most published cases describe patients who have impaired recognition of "biological" or living things such as animals, fruit, and vegetables (e.g. Hart & Gordon, 1992; Sartori & Job, 1988; Sheridan & Humphreys, 1993; Silveri & Gainotti, 1988). Some authors have partly (or

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wholly) attributed the impairment of living-thing knowledge to the confounding of category with name frequency, visual complexity, and item familiarity (Funnell & Sheridan, 1992; Stewart, Parkin, & Hankin, 1992). Nevertheless, such an explanation would not account for the occasional cases who, by contrast, experience more difficulty with man-made objects than living things (Frugoni, Paquali, Perani, & Zorat, 1998; Hillis & Caramazza, 1991; Sachett & Humphreys, 1992; Silveri et al., 1997; Warrington & McCarthy, 1983, 1987; Caramazza & Shelton, 1998). Moreover, many studies have now documented category-specific deficits using matched sets of stimuli (see Caramazza, 1998, for review).

Explanations that do not rely on the dichotomy of living/nonliving have also been proposed for category-specific impairments. Many accounts stress a critical relationship between visual information and the recognition of living things.[1] Some (e.g. Riddoch & Humphreys, 1987; Riddoch, Humphreys, Coltheart, & Funnell, 1988; Sartori & Job, 1988; Sheridan & Humphreys, 1993) have argued that category-specific deficits for living things may reflect a disorder at the level of the structural description system: i.e. the "store of perceptual knowledge of object structures used to mediate visual object recognition" (Sheridan & Humphreys, 1993, p.167). Humphreys and colleagues (Riddoch at al., 1988; Sheridan & Humphreys, 1993) make a distinction between items from categories that have highly similar perceptual structures or structural overlap (e.g. animals, insects, fruits, and vegetables) and those with structurally distinct members (e.g. clothing, tools, furniture). Since the former have a high degree of intra-category structural similarity, this "visual crowding" may make them more difficult to distinguish, and so account for the living-thing category-specific deficit (Damasio, 1990; Gaffan & Heywood, 1993; Riddoch et al., 1988; Sheridan & Humphreys, 1993).

By contrast, others have emphasised the differential weighting of certain semantic attributes in knowledge acquisition (and description). In particular, that sensory attributes may be weighted more heavily than functional attributes in acquiring knowledge of (or in recognising) living things, while the reverse may be true for man-made objects (see Farah & McClelland, 1991; Laws, 1998; Laws, Evans, Hodges, & McCarthy, 1995a; Laws, Humber, Ramsey, & McCarthy, 1995b; Silveri & Gainotti, 1988; Warrington & McCarthy, 1983; Warrington & Shallice, 1984). Nevertheless, it is also clear that a loss of visual knowledge per se is not a sufficient condition for a living-thing category-specific impairment (see Coltheart et al., 1998; and patient IW described by Lambon Ralph, Howard, Nightingale, & Ellis, 1998).

In a related vein, others suggest that the *relationship* between visual and functional attributes differs for living and nonliving things (see De Renzi & Luchelli, 1994). Specifically, living things have fewer (and relatively arbitrary) links between visual and functional attributes, while for nonliving things, function might imply appearance and vice-versa. Hence, nonliving things may be less susceptible to the effects of neurological disease, since loss of one type of attribute information (i.e. visual) may still be inferred from the other (i.e, functional), However, again, this version of the attribute approach does not readily account for the cases of relatively selective nonliving impairment.[2]

In this paper, we report a patient (SM) who, following a right-hemisphere lesion, shows a relatively selective loss of stored structural knowledge of objects, while having good associative (nonvisual) knowledge for the same items. Within the frameworks outlined above, this might be expected to impair SM's ability to recognise living things more than nonliving things. Paradoxically, the deficit appears to have greater impact on his recognition of

[1] Leaving aside those category-specific disorders that appear to reflect a lexical disorder (where extensive testing of the knowledge base has been limited to matching tasks).

[2] This model appears to critically rely upon evidence from longitudinal data showing that nonliving knowledge may return across time, while living knowledge does not (see DeRenzi & Luchelli, 1994); otherwise the model requires a large act of faith (for criticisms of this approach, see Laws, 1998).

nonliving things, consistent with recent attacks on this association (Caramazza & Shelton, 1998). A plausible model, that accounts for these paradoxical data, is presented.

CASE REPORT

The patient is an 84-year-old man (SM) with 9 years of formal education. He had been a farmer in the North East of Scotland all his life, and continued to work and live independently. He is right-handed, with no family history of left-handedness. He had no previous neurological history, before suffering a large right posterior cerebral artery infarction, involving the right posterior and inferior occipito-temporal region (see Figure 1). There was an additional lesion in the right thalamus and the posterior limb of the internal capsule, presumably part of the same cerebrovascular event. In the acute period he had a severe left hemiparesis and hemianopia. When testing began (1 month after the stroke) he was still moderately hemiparetic and, though the hemianopia had lifted, he showed mild features of visuospatial neglect and extinction. He noted (correctly) that he had suffered this problem soon after the stroke, but reported (incorrectly) that he had no current difficulty in attending to items on the left. He complained of "poor vision."

Initial investigations of visual and spatial abilities

SM's visual and spatial abilities were examined using subtests from the VOSP (Warrington & James, 1991). He performed at ceiling (20/20) on the VOSP Shape Detection Screening Test (where the presence/absence of an "X" must be

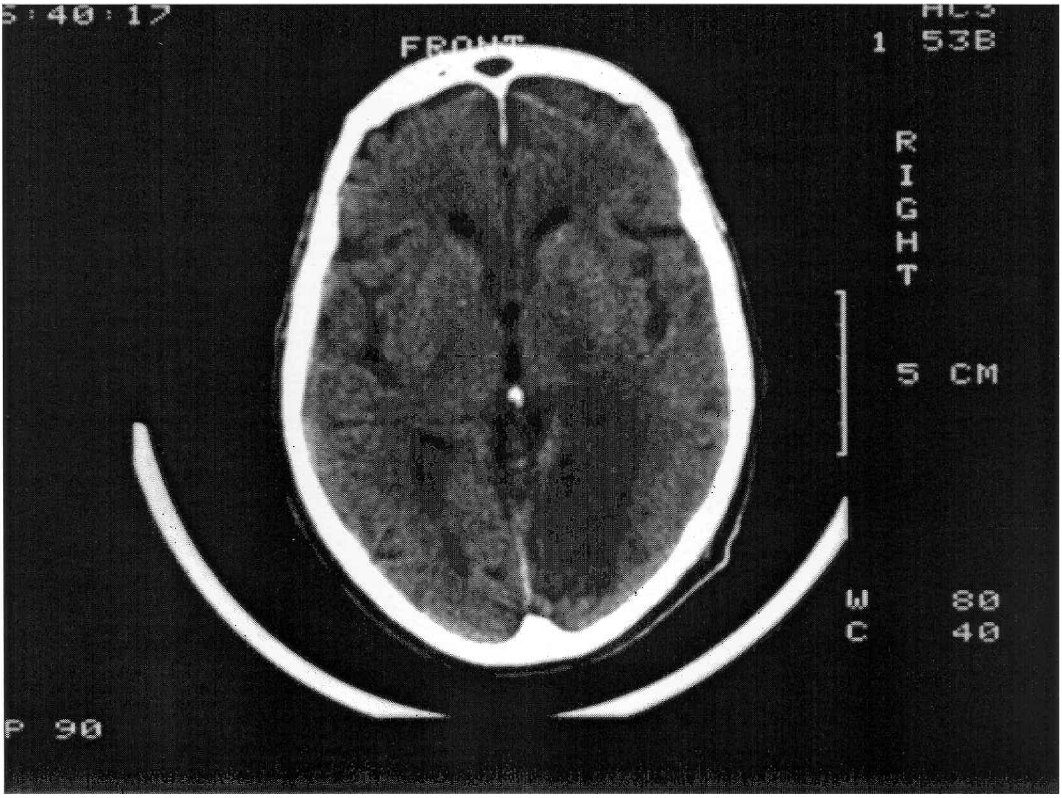


Figure 1. *SM's CT scan.*

detected amongst visual noise). He scored 7/10 on a simple Dot Counting task, where all of his errors underestimated the total by one item—possibly reflecting neglect of the leftmost item. On the Position Discrimination task (i.e. whether a dot lies centrally within the square) he also scored below ceiling but above chance (14/18), and again neglect way have handicapped his performance. He recognised only 13/20 Incomplete (i.e. degraded) Letters, and performed poorly (9/20) on the difficult Object Decision task (deciding which one of four distorted silhouettes represent a real object). He was able to identify squares from rectangles (Efron, 1968) without difficulty. Indeed, he spontaneously chose to sort these rectangular forms (flawlessly) in sequence according to their aspect ratio.

SM could copy line drawings with reasonable accuracy, though he showed some evidence of left neglect, as in his copy of the Rey Complex Figure (see Figure 2). He accurately copied (see Figure 3) several items from the Snodgrass and Vanderwart (1980) line drawing corpus (though he described himself as "never a drawer"). While copying the drawings he said: of the elephant—"it's a big beast"; of the frog—"it's another beast"; of the kangaroo—"it's hard to imagine what it is"; and that he could not really think what the "roller-skate" was. (Note that, on other occasions when directly asked to name these drawings, he *was* able to name some of them—see following.) His topographical knowledge was good; he was fully oriented within the ward, and could describe the spatial location of various rooms (including the dining room, nurses' station, and therapy rooms). He also accurately located various Scottish towns and cities on an outline map of Britain.

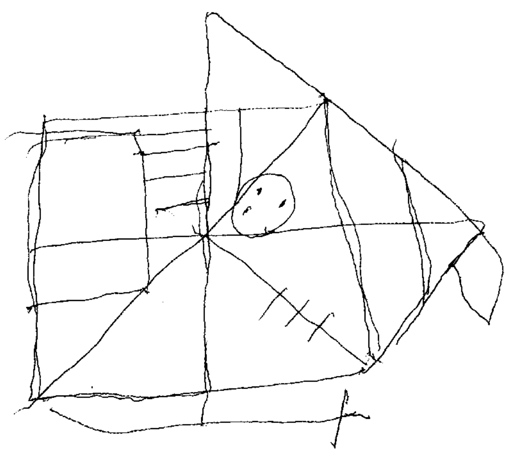


Figure 2. *SM's copy of the Rey Complex Figure.*

In contrast to these reasonable visuospatial abilities, SM's object recognition and naming was poor. He named only 1 of the first 15 items on the Graded Naming Test (McKenna & Warrington, 1983). He also named (or correctly identified by description) only 6/53 famous faces—failing to recognise such readily identifiable faces as the current Queen, Marilyn Monroe, Margaret Thatcher, Mahatma Ghandi, Elvis Presley, and Albert Einstein. He correctly read individual letters and words, but showed some neglect dyslexia when reading connected text.

Finally, on a category fluency task (how many of these can you name in a minute), SM's fluency was moderate. He produced names for 13 land animals, 6 bird species, 4 water creatures, and 3 dog breeds. He performed at a comparable level for inanimate objects, naming 9 household items, 9 musical instruments, 6 modes of land travel, and 3 modes of water travel. This suggests that he has a reasonable repertoire of animal and object names. Indeed, he provided some items on the category fluency task that he was unable to produce when attempting to name line drawings (in later tests).

Comment

SM had good elementary visual abilities, and relatively preserved spatial skills (neglect excluded) on tasks of copying and topographical knowledge. In contrast, he had profoundly impaired recognition of famous faces and common objects. This neuropsychological profile seems relatively typical for a right posterior cerebral artery infarction. The presence of hemiparesis and neglect is unusual after a lesion in this vascular territory, but is probably accounted for by the additional right thalamic-internal capsule lesion. As might be expected from a right-sided lesion, his reading ability was largely

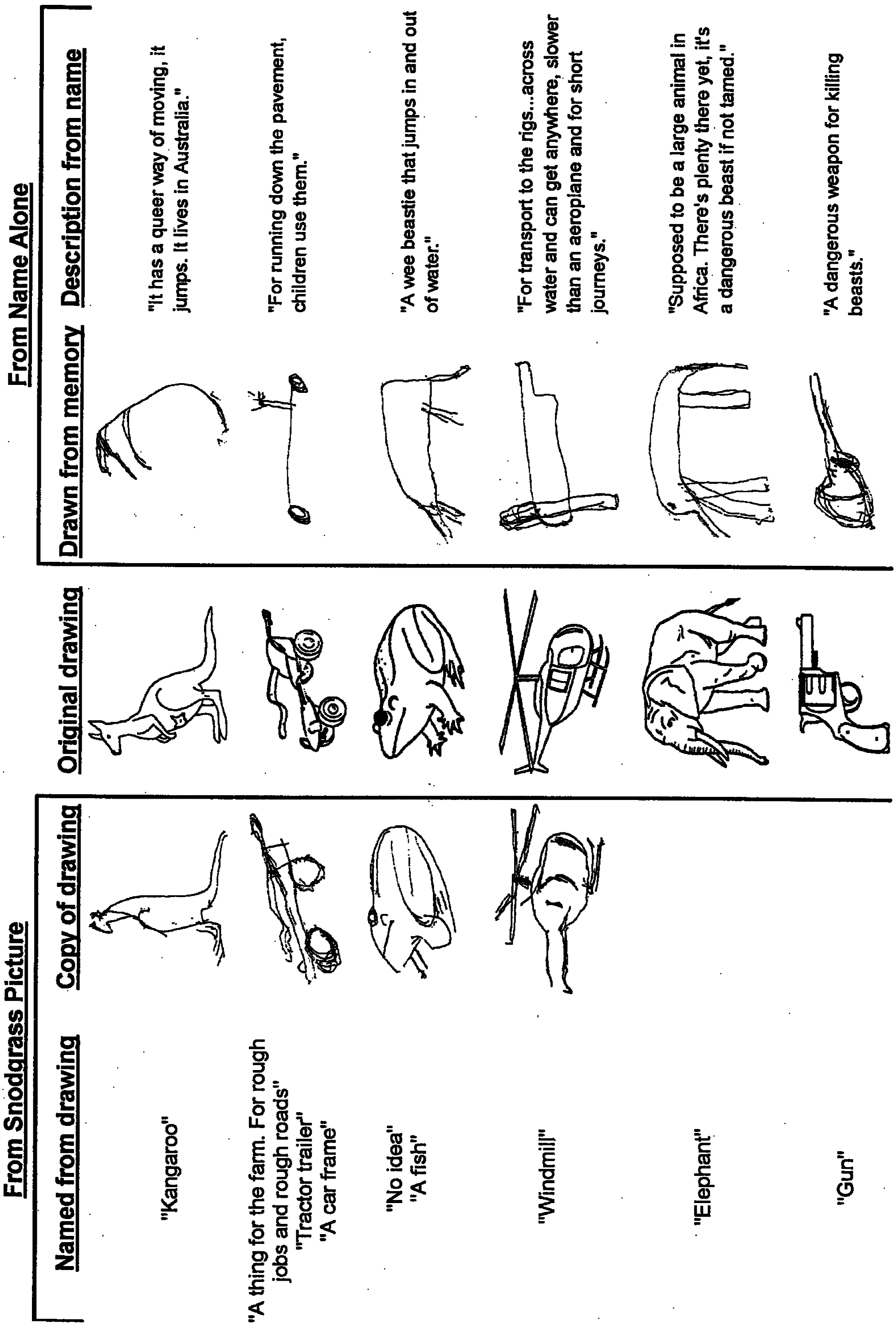


Figure 3. *To the left, SM's performance in copying and naming line drawings. In the centre, the original Snodgrass and Vanderwart (1980) stimuli. To the right, SM's performance, from name alone, in drawing the objects and in describing them.*

intact. Detailed testing focused on his visual object recognition abilities.

Naming visually presented objects

SM was asked to name 245 items from the Snodgrass and Vanderwart (1980) corpus of line drawings. He correctly named 128/245 items (52%) and showed no substantial difference in the proportion of living and nonliving items that were named (see Table 1). The items named and unnamed by SM did not significantly differ in visual complexity (3.0 vs. 2.9), familiarity (3.1 vs. 3.4), or word frequency (30.97 vs. 43.40).

Error classification

SM's naming errors were classified into five groups: (a) visual errors in which the response named a visually similar exemplar, but one that was not semantically related to the target (e.g. snail-clock; pear-bell); (b) semantic errors in which the response was semantically, but not structurally, related to the target (e.g. ear-nose); (c) visual-semantic errors, in which the response was both semantically and structurally related to the target (e.g. guitar-fiddle; sock-boot); (d) superordinate errors in which the response was the more general category name for the target (e.g. cockroach-beastie); (e) don't know responses; and (f) others (these largely refer to phonemic, circumlocutory, unrelated, and bizarre errors). None of SM's errors contained circumlocutions or were phonemic (to suggest that he had a name retrieval problem) and he did not provide descriptions of items when making errors. This classification of his errors (see Table 2) revealed a pattern that differed between living and non-living things (χ^2 (5) = 12.13, p = .03, two-tailed). In particular, he made a greater proportion of structural/semantic errors for inanimate than animate items (see Table 2) and these errors covered a broad range of specific nonliving (e.g. tools, furniture, vehicles) and living superordinate categories (animals, fruit, vegetables).

Table 1
SM's naming of Snodgrass and Vanderwart (1980) drawings

Category	*Number Correct*	*Percentage Correct*
Living		
Animals	27/36	75
Insects/birds	7/16	44
Fruit, vegetables, plants, and food	8/30	27
Body parts	5/12	42
Total living	47/94	50
Nonliving		
Furniture	13/18	72
Buildings/building parts	6/9	67
Clothing	14/23	61
Tools	11/18	61
Kitchen utensils	11/20	55
Vehicles	5/10	50
Musical instruments	1/8	13
Miscellaneous	21/46	46
Total nonliving	81/51	54

Category-specificity

Despite the lack of a category effect on the Snodgrass and Vanderwart corpus, it should be noted that this set of items differ across category on familiarity, visual complexity, and name frequency (see Funnell & Sheridan, 1992; Stewart et al., 1992). Hence, we examined SM's naming on a *subset* of "living" and "nonliving" items previously employed by Funnell and Sheridan, 1992 (see Appendix A) that were matched across category for "critical" variables.

The 60 items (31 living and 29 nonliving) were taken from 3 matched familiarity levels (high familiarity/living 4.62 vs. high familiarity/nonliving 4.69; medium familiarity 3.65 vs. 3.69; low familiarity 2.25 vs. 2.26). The total number of items were

Table 2
Different naming errors made by SM

	Living (% of all errors)	*Nonliving (% of all errors)*	*Total (%)*
Superordinate	5 (10.6)	0 (0)	5 (4.3)
Structural	13 (27,6)	23 (32.8)	36 (30.7)
Semantic	1 (2.1)	0 (0)	1 (.08)
Structural/Semantic	10 (21.2)	23 (32.8)	33 (28.2)
Don't know	12 (25.5)	19 (27.1)	31 (26.5)
Other	6 (12.7)	5 (7.1)	11 (9.4)
Total	47	70	117

matched across category (living vs. nonliving) on measures of: familiarity (3.44 vs. 3.44: $t = 0.01$ $p = .99$); visual complexity (2.97 vs. 2.65, $t = 0.24$, $p = .81$); image agreement (3.97 vs. 3.94: $t = 0\ 31$, $p = .75$); name agreement (91.65 vs. 88.84; $t = 0.86$, $p = .39$); similarity (−0.14 vs. −0.03: $t = 1.16$, $p = .25$), and age of acquisition (44.58 vs. 55.73: $t = 0.86$, $p = .39$). The first four measures were taken from Snodgrass and Vanderwart (1980), name agreement was taken from Vitkovitch and Tyrrell (1995), the measure of similarity was taken from Farah, Hammond, Mehta, and Ratcliff (1989), and the age of acquisition measure from Morrison, Chappell, and Ellis (1997), Although the *inanimate* items reflected a variety of categories, the *living* things within each familiarity range tended to come from different subcategories: the high familiarity living things consisted mainly of body parts (6/9); the medium familiarity living things were mainly fruit/vegetables (10/11); and the low familiarity living things were wholly animals (11/11)[3].

A two-way ANOVA revealed that SM's naming was not significantly influenced by familiarity, $F(2, 59) = 2.86$; $p > .05$, or category, $F(1, 59) = 0.44$, $p > .05$. However, the interaction between category and level of familiarity was highly significant, $F = (2, 59) = 5.65$, $p = .006$). Table 3 shows that SM named significantly fewer nonliving than living items from the low familiarity range ($\chi^2 = 8.42$, $p = .003$). Table 3 also documents the performance of 39 normal undergraduate subjects when naming the same stimuli, but in a speeded (20 ms) presentation paradigm (Laws & Neve, 1999). The results suggest that JB's performance is an exaggeration of the "normal" profile (at least as elicited in this speeded presentation paradigm).

Comment

SM showed no significant difference in the proportion of living and nonliving items named on the full Snodgrass and Vanderwart corpus. Similarly, he showed no significant main effect for category on the matched Funnell and Sheridan subset; however, his naming did reveal a significant interaction between category and familiarity: naming significantly fewer nonliving than living items from the *low* familiarity range. Further analyses showed that SM's naming of fruits and vegetables (medium familiarity) was no worse than matched inanimate items; and his naming of body parts was no worse than for matched inanimate high familiarity items. Thus, SM's pattern of deficit (i.e. greater for nonliving things) mirrors other category-specific cases who have living-thing deficits restricted to low familiarity items (Funnell & DeMornay Davies, 1996; Gainotti & Silveri, 1996; Sartori, Job, Miozzi, Zago, & Marchiori, 1993). In this respect, these data confirm the importance of familiarity for retrieval from semantic memory (see Laws in press; Laws & Neve, 1999). In addition, most of SM's naming errors the reflected the structural (or structural/semantic) properties of the targets, which is consistent with his being visually agnosic (see Farah, 1990; Levin 1978; Ratcliff & Newcombe, 1982). Indeed, it might be argued that the nonliving deficit shown by SM permits a clearer separation of visual and visual/semantic naming errors than is possible in typical living disorder cases (where the errors often reflect a mixture of visual and semantic similarity and cannot be easily attributed to either).

Naming for items excluding musical instruments and body parts

The previous set (taken from Funnell & Sheridan, 1992) contained both body part and musical instrument items, which are somewhat unusual since the former tend to be impaired along with nonliving things and the latter along with living things (see Warrington & McCarthy, 1987). We therefore reexamined SM's naming on a second set of 36 line drawings (18 animals and 18 nonliving things) that did not include either body parts or musical instruments. The pictures were drawn from the low

[3]This set of items is not ideal. For example, whether body parts might rightly be considered "living things" is debatable. In addition, the inclusion of body parts in the "living" category and musical instruments in the nonliving category also raises problems (see following). Nevertheless, this set has been used to explore category-specific deficits in a variety of patients by a variety of researchers, and thus provides a reasonable point of comparison (see Farah, Meyer, & McMullen, 1996).

Table 3
Living and nonliving items named by SM and normal controls at different levels of familiarity

	High Familiarity	*Medium Familiarity*	*Low Familiarity*	*Total*
Living				
SM	5/8 (.62)	7/12 (.58)	8/11 (.73)	20/31 (.64)
Controls	6.78 (.85)	9.58 (.80)	8.00 (.73)	24.36 (.78)
Nonliving				
SM	7/8 (.87)	8/11 (.73)	1/10 (.10)	16/29 (.55)
Controls	7.33 (.92)	8.58 (.78)	3.40 (.34)	19.31 (.66)

The control subjects (n = 39) were undergraduates who named the items in a speeded presentation paradigm (20 ms) exposure

familiarity range of the Snodgrass and Vanderwart corpus (taken from Laws et al., 1995a; see Appendix B & C), and were matched across category on measures of familiarity (living/nonliving 2.09 vs. 2.15), name frequency (24.74 vs. 27.9), visual complexity (3.77 vs. 3.68), and age of acquisition (52.92 vs. 71.33). This test was repeated twice more in later sessions to investigate SM's response consistency.

One month after the stroke, SM recognised only 6/18 nonliving and 14/18 living items. In the second session (2 months post-stroke) he recognised 7/18 nonliving and 13/18 living items, and finally, in the third session (3 months post-stroke) he recognised 10/18 nonliving and 14/18 living items. Thus, SM's naming of nonliving items did improve over time (becoming nonsignificantly different from living things by the third session) and we cannot therefore exclude the possibility of some practice effect. Nevertheless, when the data are examined for all three sessions, SM named significantly more living than nonliving items ($\chi^2 = 12.43$, $p < .001$). Again, SM's nonliving naming errors largely reflect visual similarity (see Appendix C), with 45% being classifiable as structural, 26% as "don't know", and the remainder being structural/semantic or other.

Real objects, photographs, and line drawings

To test whether SM's recognition difficulties occurred with three-dimensional objects as well as line drawings, he was asked to name 22 real objects and object-models. Eleven were animate objects (all animal models) and 11 were inanimate objects (10 real, and 1 model helicopter). He correctly recognised 21 (11 animate, 10 inanimate). When the same objects were presented as colour photographs (in a different session), his performance dropped to 11 animate, 8 inanimate. In a final session, we examined his identification of line drawings of same items, and he named only 9 animate and 4 inanimate items. So, although SM's naming of living things was largely unaffected by mode of presentation, his naming of nonliving things was substantially affected by mode of presentation. Comparisons revealed that SM showed significantly better naming of inanimate items from real objects as compared with line drawings (Fisher's Exact Probability: $p = .01$). No other comparison was significant.

Comment

SM's identification of line drawings was poor (roughly 50% correctly identified), with his naming of nonliving items being significantly worse than that for living things. Moreover, his naming was significantly worse for nonliving things within the low familiarity range (he showed no significant category effect for high/medium familiarity items). On a subset of low familiarity living and nonliving items, that were stringently matched across category for potential artefacts, SM was again significantly worse at identifying nonliving things. Since SM's deficit for nonliving things could still be demonstrated using these matched items that did not include body parts or musical instruments, this confirms that his deficit is not an artefact of using one of the variety of "critical" variables that have previously been argued to spuriously produce "category-specific" deficits. In addition to artefactual variables such as familiarity, which been widely controlled for in previous studies, age of acquisition is also a potential confounding variable in cases where nonliving items are differentially impaired (see Lambon Ralph et al., 1998; Morrison et al., 1997; Tranel, Logan, Frank, & Damasio, 1997). Hence, it is notable that SM's deficit for nonliving things also occurred on two picture sets that were matched across category for (true) age of acquisition (using the Morrison et al. measure derived from 280 children).

SM's poorer naming of low familiarity nonliving items also requires further examination because of his occupation. One possibility is that, being a farmer, SM's better naming of living things may reflect his (idiosyncratic) greater familiarity for animals[4]. This does, however, seem unlikely. If, as a farmer, he was especially familiar with animals by virtue of his work, we might expect this to selectively affect his naming of native animals. However, a post hoc analysis of SM's naming for the native and non-native animate things from the entire Snodgrass and Vanderwart corpus revealed no difference (native 66% vs. non-native 70% named). In addition, his naming of native and non-native animals in the familiarity matched set was also comparable (native 75% and non-native 80% respectively: see Appendix B).

Finally, SM's object recognition was better with real objects than photographs or line drawings, and this finding reached significance for nonliving things. His recognition deficit therefore shows a gradient of performance decline as a function of stimulus type that has been reported by a number of agnosia investigators (see Farah 1990; Levine, 1978; Ratcliff & Newcombe, 1982; Rubens & Benson, 1971). The most widely accepted explanation is that progressively more visual information (e.g. texture, colour, depth, real-world size, etc.) is available as one moves from line drawings to real objects. Thus, patients such as SM can more easily compensate for their recognition impairment when viewing a real object (rich in visual cues), where the information for such compensation strategies are available. Stimulus type does not appear to have any direct bearing on SM's poorer recognition of nonliving item's—except that the difficulty with nonliving items becomes more marked for items that are more difficult for all agnosic patients to recognise.

Structural knowledge

The following tasks were designed to analyse whether SM's poor naming of inanimate things reflected a disorder at the level of structural descriptions. We examined his ability both to *address* stored structural descriptions (i.e. retrieve existing knowledge of the structure of objects) and to *derive* novel structural descriptions (i.e. develop knowledge of the structure of unfamiliar objects).

SM performed poorly on a forced-choice Object Decision task (Riddoch & Humphreys, 1993), requiring the classification of objects as either "real" or "unreal" (i.e. chimeric). He scored 25/32 on the "Easy" and 17/32 on the "Hard" item versions of the task—both scores fell outside the normal range for 50–80-year-olds. There were too many living-thing items to permit an analysis by category.

In contrast to his poor object identification abilities, SM could copy line drawings with reasonable accuracy (see Figures 2 and 3)—including some objects that he failed to recognise. Further evidence of his good ability to extract object structure from vision comes from the BORB Unusual Views matching task (Riddoch & Humphreys, 1993). This task requires matching a target photograph of an object with one of two other photographs (placed below and to the left and right of the target)—one consisting of the same object photographed from a different viewpoint and one a picture of a different object. The "different" view-

[4]We would like to thank one of the reviewers for pointing out this possibility.

point either alters the view of the principal axis of the object (the Foreshortened condition) or occludes an important object component (the Critical Feature condition). SM correctly chose 17/25 on the Foreshortened items, and 21/25 of the Critical Feature items, both scores within normal limits for 50–80-year-old subjects.

Comment

SM could correctly match objects across different viewpoints, and could copy line drawings of objects. This suggests that he could derive stable representations of object structure from vision, even in tasks where such knowledge is tapped across different viewpoints (i.e. object constancy). In contrast, he was impaired at distinguishing real and unreal objects on a task thought to directly tap existing knowledge of object structure (Riddoch et al., 1988). This dissociation between SM's intact object matching and his impaired object decision performance indicates that the process required for mapping object structure across two views of an object is separable from that required for judging object familiarity. It suggests that SM has a specific problem with *stored* structural knowledge of objects, while remaining able to *derive* structural descriptions from the visual world.

Verbally presented questions about objects

Definitions from name alone

To determine SM's verbal knowledge base for objects, he was asked to describe objects from their names alone, using the 36 items previously presented as pictures for naming, This was examined during a separate test session (between administrations one and two of the picture naming tasks). SM's performance was compared with five closely matched control subjects on this task. All were men, aged 76, 81, 84, 87, and 88, who (like SM) had left school at 14. All had (like SM) spent their entire working lives on farms in the rural North East of Scotland (three cases) or rural North West Wales (two cases). All were still working, and living independently.

SM provided concise and recognisable descriptions for 35/36 of the items. His sole error was for "spinning wheel" which he described as "for drawing water from a well, the wind drives them, they can be big ... 12 feet or more..."—the appears to reflect some confusion with a windmill, rather than a lack of knowledge for the properties of a spinning wheel. All other responses were appropriate—for example: "camel" (which he once misrecognised, from vision, as a giraffe) was described from name as "an animal, they work in sunny countries, can do long journeys without food or water in the desert"; and "helicopter" (misrecognised once as a windmill), was described from name as "for transport to the rigs ... across water, and can get anywhere ... slower than an airplane, but good for short journeys."

SM's and the control subjects' descriptions were scored for "associative/functional" and "structural" attribute content. Responses were scored as structural if the attribute could be directly derived from visual inspection of the item; responses were scored as associative if the information was not directly available from visual inspection of the item. This showed that, in contrast to controls, SM's descriptions were dominated by *associative* attribute knowledge (see Figure 4). He produced associative/functional information for the majority of both living and nonliving items (17/18 vs. 15/18 items). However, he produced structural information to significantly more living than nonliving things (13/18 vs. 4/18: $\chi^2 = 9.03$, $p < .003$). He made only two errors of associative knowledge, and both were for living things: suggesting that penguins live "in Africa ... in hot countries," and that a rhinoceros tends to live in water (perhaps a confusion with hippopotamus).

From the total of 79 attributes produced by SM, 58 (73%) were associative (e.g. anchor "for stopping ships"). Although associative attributes are generally thought to be more commonly provided for nonliving things (see Laws et al., 1995a, 1995b), SM provided significantly more for *living* things (33 vs. 25: $\chi^2 = 4.66$, $p = .03$). By contrast, only 21/79 (27%) of his responses contained *structural* information. As anticipated, structural information was more common for living things (17/21), with only four structural responses for nonliving items. Not only did SM provide few pieces of structural

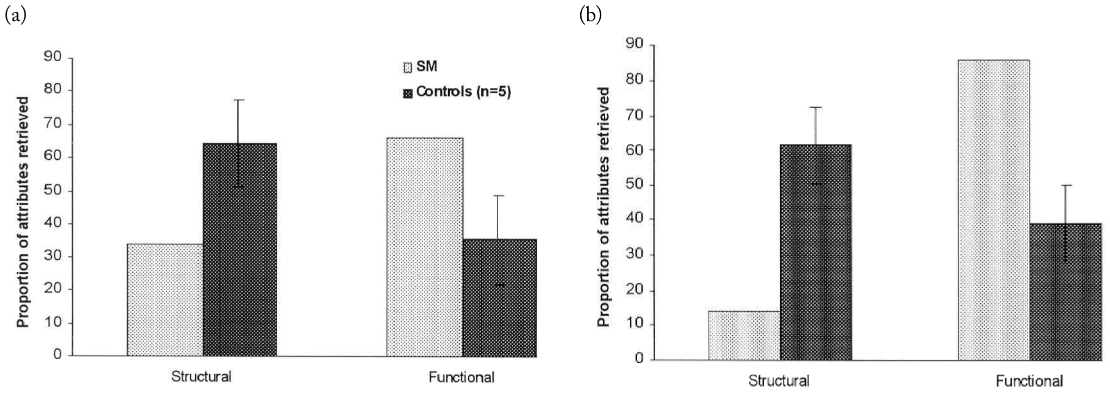


Figure 4. *SM's and five control subjects', performance on a task of description from name alone: (a) living things; (b) non-living things. The error bars represent one standard deviation.*

information, but those that he did were impoverished, almost all being crude estimates of size. For example, his so-called "structural" information for the items frog, squirrel, goat, zebra, fox, and clothes-peg was merely "a small thing" or "a wee beastie."

Comment

Control subjects showed a tendency to provide more structural than functional (associative) information in their definitions, though the difference was greater for living than nonliving things. In direct contrast, SM provided many more functional/associative information than structural information. This was especially marked for nonliving things, where 86% of his responses were functional/associative.

Thus, though SM is able to define objects from name alone, these data suggest that his definitions rely heavily on functional/associative knowledge. That is, SM appears to have a disturbance of his knowledge base of object structural descriptions—a deficit that is more marked when dealing with nonliving objects. These data confirm the earlier findings that suggest that SM is able to *assemble* structure descriptions of seen objects, but is markedly impaired when required to access his *stored* knowledge base—whether this is knowledge is tapped in tasks of object recognition, description from name alone, or drawing from memory. Finally, note that the profile of performance observed in SM cannot be attributed to his age, background, education, or occupation, since this profile differed dramatically from that of the five closely matched control subjects.

Verification of visual and verbal statements

Although SM has difficulty generating structural information (i.e. recall), it remains possible that he could perform the simpler task of attribute verification (i.e. recognition). To test this, we examined his ability to verify true and false structural and associative attributes, for living and nonliving things, presented verbally (taken from Sheridan & Humphreys, 1993). Note, however, that Sheridan and Humphreys' patient was 19 years old, and their control data were derived from sibling and age-matched controls—whose performance was near to ceiling. To examine for possible age effects, two of the controls used on the previous task (the Welsh farmers, aged 84 and 88) were also given these tasks.

To tap associative/functional knowledge, SM was presented with 60 forced-choice true or false statements (e.g. rats can carry disease; we get wool from cows; fridges keep food warm; soap is used for washing hands). He correctly answered 59/60 (98%) of these attribute questions, and showed no category effect (19/20 inanimate objects, 20/20 animals, 20/20 foods). This performance is within the normal range for Sheridan and Humphreys' (1993) younger controls. Both of SM's age and occupation-matched control subjects scored 60/60.

Similarly, SM was given a series of forced-choice true and false visual attribute questions to tap knowledge of object structure (an egg cup has a handle; buttons are usually round; a zebra has a striped coat; a deer has a horn on its nose). By contrast to his normal verification of verbal attributes, SM correctly answered only 39/50 (78%) of the visual attribute questions (15/20 inanimate objects, 17/20 animals, 7/10 foods). This performance is well outside the normal range for Sheridan and Humphreys' (1993) younger controls. The two age-matched control subjects scored 48/50 (96%) and 49/50 (98%). Although the questions tapping structural and associative knowledge were not matched for difficulty, SM correctly answered significantly more associative than structural questions (Fisher's Exact Probability: $p = .003$).

Comment

SM was able to answer forced-choice questions about functional/associative knowledge with a high level of accuracy (98% across all categories), within the normal range even of young controls. In contrast, his ability to answer forced-choice questions about structural knowledge was much poorer (78% across all categories), and outside normal limits. So, as demonstrated in the previous task of description from name alone, SM's knowledge about objects was selective, being far poorer for information about object structure.

DISCUSSION

Following a right-hemisphere lesion, SM had impaired object recognition that was significantly worse for the "category" of nonliving things. As discussed later, we do not consider "category-specificity" to be an adequate description of SM's deficit. Nevertheless, in the context of recent discussions on this topic (Caramazza & Shelton, 1998; Funnell & Sheridan, 1992; Lambon Ralph et al., 1998; Stewart et al., 1992; Tranel et al., 1997), we should carefully address, and attempt to reject, other possible artefactual and personal explanations for his performance. Notably, "category" effects were found even when the stimulus set had been controlled for familiarity, visual complexity, name frequency, and age of acquisition. In addition, it might be argued that SM's career as a farmer has provided him with some pre-existing advantage in the recognition of living things, or disadvantage him for the category of nonliving things. We consider this unlikely, given that his performance differs so strikingly from that of five controls matched for age, education, sex, and occupation. Moreover, if this was true then we might also expect him to show better naming and recognition of domestic farm animals (which he did not; naming equivalent numbers of domestic and nondomestic animals). There seems no obvious reason why a Scottish farmer should have better recognition of zebras, giraffes, and other nondomestic animals (of which he has had little direct experience), rather than for barns, clothes-pegs, and chisels (which he would have encountered more often).

However, though we do not feel that SM's "category" effect reflects an artefact of the variously cited "critical" variables (such as familiarity) or occupation, his pattern of deficit *can* perhaps better be accounted for in terms of more recently proposed accounts stressing the role of stored structural knowledge (e.g. Riddoch & Humphreys, 1987; Riddoch et al., 1988; Sartori & Job, 1988; Sheridan & Humphreys, 1993). Hence, it is notable that SM retained good elementary visual abilities and could *derive* information about object structure on tasks that did not tap his stored knowledge about object shape (e.g. copying line drawings and matching objects across different viewpoints). By contrast, he was impaired on all tasks that tapped *stored* structural knowledge. This deficit was apparent in his poor structural knowledge on orally presented forced-choice tests, and on an object decision task. Similarly, although SM *could* describe items from name, these descriptions strongly favoured information about the functional/associative properties of objects, and contained impoverished structural knowledge (especially for nonliving items). This all suggests that he has a disorder affecting primarily the *stored* knowledge of object structure, though he remained able to assemble novel structural descriptions. Also congruent with his having an impairment at the level of structural descriptions, the majority of SM's naming errors reflected the structural features of the targets. Since the deficit was apparent for both visually and orally presented tasks, SM's case is consistent with the claim of a modality-independent stored structural description system (Hillis & Caramazza, 1995; Riddoch et al., 1988; Schnider, Benson, & Scharre 1994).

SM's case is intriguing because he appears to be the first case of a "category-specific" recognition disorder for nonliving things who could be tested verbally. All other cases have been aphasic (see reviews by Gainotti, Silveri, Daniele, & Giustolisi, 1995; Saffran & Schwartz, 1994), where testing was limited to matching tasks. Also, SM presents with a lesion that appears to be restricted to the right hemisphere, leading to an object recognition disorder in which copying is relatively preserved (classically, an "associative" agnosia). This contrasts with the bilateral, or left-sided, inferior tempero-occipital lesions typically found in patients with visual agnosia but preserved copying abilities (for reviews, see Farah, 1990; Iorio, Falanga, Fragassi, & Grossi, 1992). The site of SM's lesion also differs from that reported in other patients with category-specific deficits for nonliving things (for a review see Caramazza & Shelton, 1998; Gainotti et al., 1995; Silveri et al., 1997), all of whom were aphasic following left-hemisphere lesions (those with living-thing deficits having bilateral temporal lesions: see Gainotti et al., 1995). Of course, our anatomical data derive only from SM's CT scan, and it is possible that a small left-hemisphere lesion was undetected using this imaging process. It is also possible that SM has unusual cerebral asymmetry of function (though SM is a dextral, with no family history of sinistrality). Nevertheless, all the available evidence suggests that SM's lesion site is atypical.

Given SM's loss of structural knowledge, and that the locus of his lesion is in the right hemisphere, some parallels might be drawn with theoretical notions about optic aphasia. Coslett and Saffran (1989, 1992) have argued that the residual ability of optic aphasics to recognise objects (by gesture, or on sorting tasks) might reflect the semantic analysis available to the right hemisphere. Indeed, these authors argue that the right hemisphere can process visual information up to the level of structural descriptions, and then activate its own semantic store for subsequent object recognition. The potential of the right hemisphere to perform semantic analysis is typically viewed as less than that of the left hemisphere, and may be limited to perceptual processing (De Renzi & Saetti, 1997)—while the left is viewed as the province of *true* semantic processing (Hills & Caramazza, 1995). In this context, it might be argued that SM shows a *loss* of the right-hemisphere semantic system that is claimed to be intact in optic aphasia (Hillis & Caramazza, 1995; Schnider et al., 1994). Within such an account, SM's semantic system *proper* would be intact in the undamaged left hemisphere, but this system would lack information from the damaged right-hemisphere perceptual system about the structural properties of objects. Hence, he could provide associative/functional information (from the left hemisphere), but little structural knowledge (from the right hemisphere). However, it also is possible that stored structural knowledge may be available to systems in both hemispheres, or that SM may have an unusual pattern of cerebral dominance. We do not wish to enter into a debate on matters of lesion laterality (of the type that has so troubled the prosopagnosia literature, for example), or of the implications of these data for the organisation of semantics across the two hemispheres. Nevertheless, SM's lesion site is clearly unusual in the context of other cases who present with a disturbance of object knowledge.

Animate-object structural overlap reconsidered

As it stands, this neuro-anatomical account does not explain why a disorder of stored structural knowledge should differentially impair the recognition of nonliving things. Indeed, this association has recently been questioned (Caramazza & Shelton, 1998). An "artefactual" argument is commonly used in the literature to explain the category-specific impairments for living things. It is argued that living things are difficult to recognise because they have greater structural overlap—i.e. within-category "crowding". For example, Gaffan and Heywood, (1993, p. 126; our italics) argue that "... there is no compelling evidence as *yet* to reject the hypothesis that ... living things are harder to identify than nonliving thing." We would argue that, by contrast, there is no compelling evidence that living things *are* harder to identify.

Although evidence from studies of normal controls does show that naming reaction times are delayed for visually similar neighbours (exclusively living things: Humphreys, Riddoch, & Quinlan, 1988; Riddoch & Humphreys, 1987), the evidence from error rates is less clear. Whereas Vitkovitch, Humphreys, and Lloyd-Jones (1993) found a greater error rate for structurally similar items (on a naming-to-deadline task), Humphreys et al. found no difference in the error rates to structurally similar and dissimilar items (on an unspeeded task). More importantly, although these studies controlled for the effects of name frequency, neither study controlled for visual complexity or familiarity. Using a rapid presentation paradigm (20 ms exposure), Gaffan and Heywood (1993) also found a greater error rate for living things; however, they failed to control for any confounding variables. The question of whether living things are more difficult to identify in normal subjects has not been adequately answered by those studies. Nevertheless, one recent study (Laws & Neve, 1999) that matched across category on all critical variables, found consistently poorer naming of nonliving than living items in a rapid presentation paradigm (20 ms exposure). The same advantage for naming living things emerged across subject and item; on two different picture sets; on the same picture set across time; and across two different groups of normal subjects.

One possibility is that the degree of structural overlap of nonliving things may have been underestimated, since some categories of nonliving items (e.g. tools, musical instruments) have quite high structural overlap. Such an account might even be consistent with the large number of structural/semantic errors made by SM to nonliving items (cf. Vitkovitch et al., 1993). Nevertheless, it would not explain why SM has better naming of other items thought to have the *greatest* structural overlap (e.g. animals). SM's case is also difficult to reconcile with the notion that living things are represented primarily by their sensory (e.g., visual/structural) attributes, while nonliving things are represented primarily by their functional qualities (Farah & McClelland, 1991; Laws, 1998; Laws et al., 1995a; Silveri & Gainotti, 1988; Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984). An expanded, or alternative, account is therefore necessary—one that incorporates the manner in which a deficit of structural description knowledge might differentially impair the recognition of nonliving things (see Laws & Neve, 1999).

It is also not transparent in what sense nonliving things are more "familiar" than living things (see Laws & Neve, 1999). The significant interaction between category and familiarity in SM's naming is similar to that found in the "living thing" cases—who typically perform worse with low familiarity living things (e.g., Funnell & De Mornay Davies, 1996; Gainotti & Silveri, 1996; Sartori et al., 1993). Although this confirms the importance of familiarity to semantic memory retrieval (cf. Funnell & Sheridan, 1992; Stewart et al., 1992), it undermines the notion that category-specific deficits for living things largely reflect their having lower familiarity than nonliving things. Funnell and colleagues have argued that we are less familiar with the physical features of many living things because they are less readily available for detailed visual inspection or palpation (Funnell & Sheridan, 1992; Funnell & De Mornay Davies, 1996). Nevertheless, this measure of familiarity captures only the degree of experience with an object or concept, and so may be an epiphenomenon of acquisition; and it does not capture the qualitative aspects of familiarity—which may be more illuminating (see Laws, in press; Laws & Neve, 1999). For example, although most people are "familiar" with monetary denominations (e.g., handling them every day), we pay little attention to the appearance of notes and coins. By contrast, our attention may be drawn towards living things *because* of their physical appearance—perhaps because they are "exotic". Indeed, Laws and Neve (1999) have found that, contrary perhaps to expectation, normal subjects rate living things as significantly more familiar than nonliving things on a measure of *visual familiarity* (the extent to which you are familiar with the way something looks). So, again, we are inclined to reject the commonly held view that nonliving things are more familiar—it depends on what one means by "familiar", and upon the individual concerned (see Laws, in press for gender-related differences).

Structural descriptions reconsidered

It has been noted that living things (at least in the Snodgrass & Vanderwart, 1980 corpus), have greater structural overlap (e.g. Riddoch & Humphreys, 1987; Riddoch et al., 1988; Sheridan & Humphreys, 1993), or between-item "visual similarity" than nonliving things (see Gaffan & Heywood, 1992). Hence, cows look structurally similar to horses, pigs, and dogs in being quadrupeds, while telephones look dissimilar to cars, chairs, and clocks. In other words, most mammals share the same set of basic component parts, differing mainly in terms of the aspect ratio of these components (cf. Biederman, 1987). Because of their structural similarity, it is argued, living things will be *harder* to discriminate than nonliving things. This argument clearly has some basis, and may well account for the findings with some patients (i.e., patients with living-thing recognition impairments). Nevertheless, SM was, if anything, *better* at naming items that were structurally similar rather than dissimilar. In this context, we note that the concept of "structural descriptions" is not unidimensional, and other factors are likely to influence the matching of input with stored descriptions of objects. In this regard, the argument that has traditionally linked impairments of structural knowledge per se with selective deficits of living things might be questioned (see Laws & Neve, 1999).

There is *another* sense in which living and nonliving things differ structurally, and here the vector of "difficulty" appears to run in the *opposite* direction to that noted. In order to consider this variable we should not focus on comparisons *between* items of a different class (i.e. dog vs. horse vs. pig), but on the extent of variability *within* a single class of object (i.e. how much is a horse like other horses?). Considered in this sense, the structure of living things may be argued to be more reliable, or "predictable", than that of nonliving things. That is, members of a given species (having the same entry-level name) have the same basic structure and organisation of component parts. Because of their close conformity to a standard, or prototype, living things might therefore be argued to provide more useful visual clues to their identity, and less misleading or ambiguous information. Thus, one cow tends to look similar to another, so that the perceived image of the object will probably (viewpoint aside) differ little from the stored-knowledge version of that object. By contrast, nonliving things, of any particular kind, often differ dramatically in terms of their colour, texture, and the aspect-ratio of their component parts: for example, cars and clocks may come in a wide range of sizes and colours, as well as varying in more basic structure: being slim or chunky, rounded or rectangular—yet all must still be classified as cars or clocks. In some instances the objects may even differ in the addition, deletion, or complete transformation of their component parts—as in the case of traditional versus mobile phones; or the range of classic chairs, rocking-chairs, and wheeled office chairs (see Figure 5a and b). So, although one class of living things may have greater structural overlap with another class, object structure within that class is highly stable: having great "representational redundancy". This would make the precise appearance of living things *less* important because they are so predictable, and hence make our knowledge of them more resistant to the effects of disruption than nonliving things. Hence, living things might arguably be *easier* for patients such as SM to recognise, primarily because the image of the to-be-recognised object would be so similar to that in stored knowledge. This might also partly explain the more accurate naming of nonliving objects by normal subjects when other artefactual variables are controlled (Laws & Neve, 1999). Although we have no commitment to the impact of evolutionary pressures on object recognition systems (Caramazza & Shelton, 1998), Laws and Neves' findings might be considered consistent with this notion.

(a)

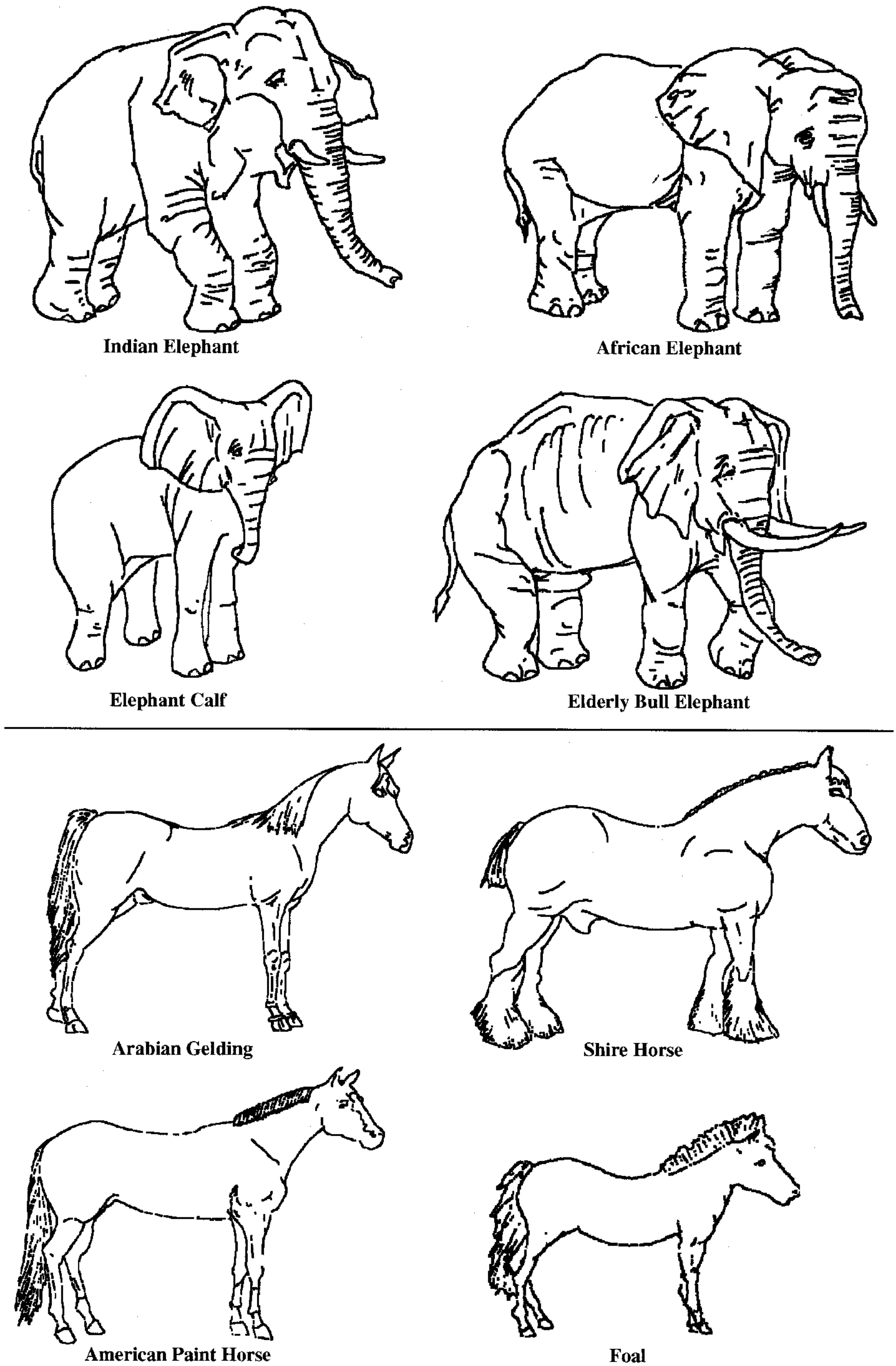
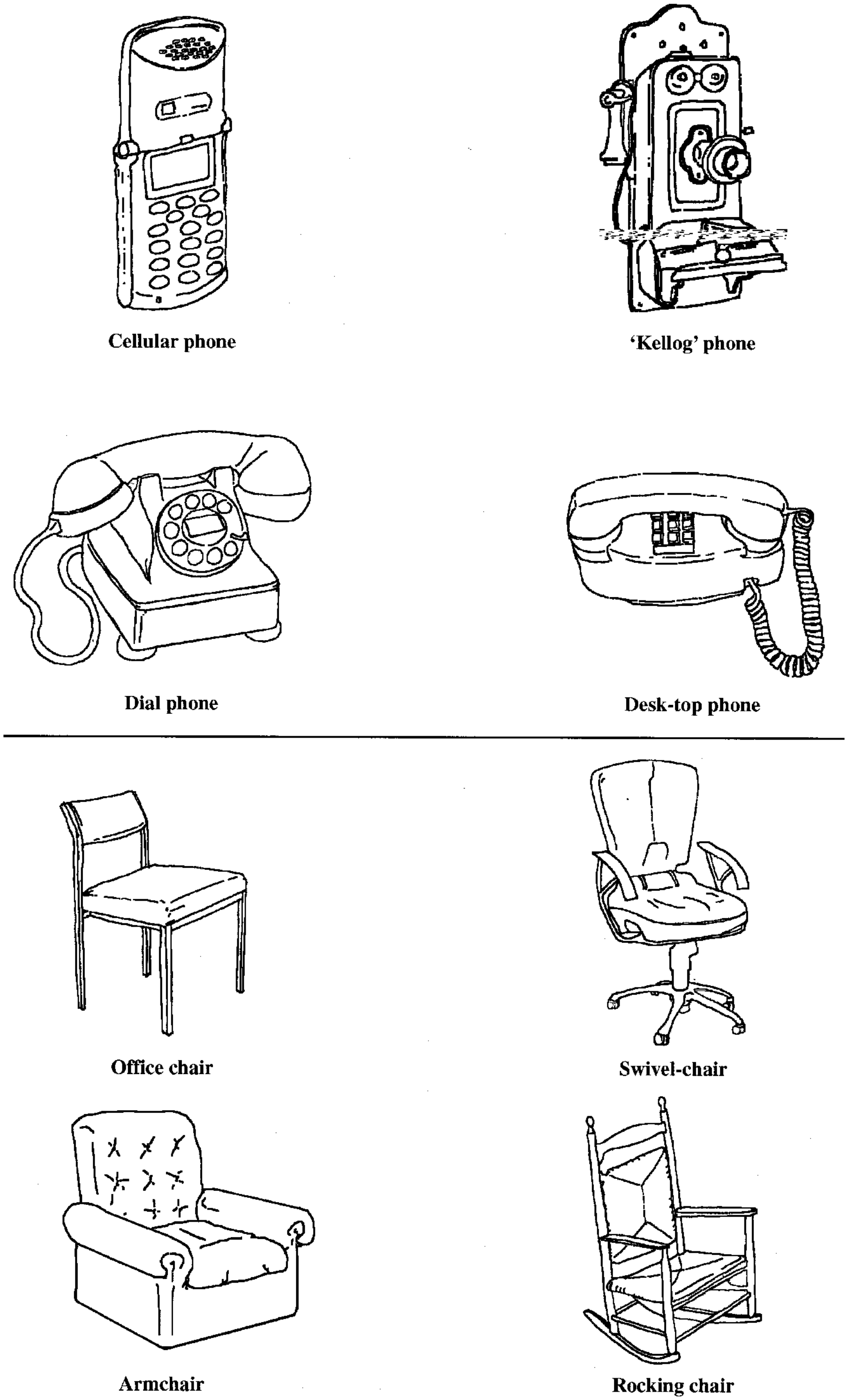


Figure 5. *A range of (a) living and (b) nonliving things, showing the extent to which objects match a "prototype". Images have been matched for viewpoint, and chosen to reflect the maximum possible structural diversity for a given entry-level name (i.e. we tried to find exemplars of "elephant" and "telephone" that were as structurally diverse as possible. Note that the nonliving things (telephone and chair)*

(b)



show enormous diversity in terms of object structure. These include additional or missing components such as the telephone's receiver, cord, and dialing mechanism, and also a wide range of chair legs and arm-rests. In contrast there is far less structural diversity for the horse and elephant items.

To quantify this issue empirically, we asked 20 normal subjects (all University undergraduates) to rate the 260 names from the Snodgrass and Vanderwart (1980) corpus for the extent to which a given real-world item had similar visual representations to other items with the same name—a variable which we will refer to as *within-item structural diversity* (see Appendix D). Specifically, they were presented with the name and asked to rate (on a scale of 1–5; 1 = very dissimilar; 5 = very similar) the extent to which all the items with the name (dog, fork, etc.) have similar structural representations[5]. We found that normal subjects rated nonliving things as having significantly greater structural diversity than living things (mean for nonliving things = 3.61 (SD = 0.62); mean for living things = 4.16 (SD = 0.60): $t_{(249)} = 6.81, p < .0001$). A comparison of SM's named and unnamed items revealed that the former had significantly less within-item structural diversity (named 3.95 (SD = 0.63) vs. unnamed 3.69 (SD = 0.70): $t_{(234)} = 2.96, p = .003$). Finally, a simultaneous logistic regression analysis (using age of acquisition; log name frequency; familiarity; visual complexity; visual familiarity[6], and within-item structural diversity as predictors) showed that the only significant predictors of SM's naming for the whole Snodgrass and Vanderwart corpus were within-item structural diversity (Wald = 5.6, $p = .018$) and age of acquisition (Wald = 12.2, $p < .001$). As noted earlier, age of acquisition is likely to be a relevant variable in cases where patients show nonliving disorders (since living things tend to be acquired at an earlier age; Howard et al., 1995—though note that SM's worse naming of nonliving things continued to occur on sets matched across category for age of acquisition). Importantly, however, the variable of within-item structural diversity was a significant predictor of SM's naming performance. This is consistent with our claim that within-item structural diversity produces a vector of "difficulty" that runs counter to that which had previously been employed—specifically, a structural variable on which nonliving things are more difficult to recognise.

Of course, it is always possible to think of *some* living things that have great diversity of form under a common entry-level name, and vice versa. However, these data suggest that that, in general, nonliving things tend to show greater structural diversity than living things. This factor may well be important for the way in which semantic knowledge might appear to break down in "categories" where the real origin of the difference in performance is a variable such as integrity of stored structural knowledge. At very least, this idea should make us think carefully about the many complexities that underlie semantic organisation[7], and make us choose carefully when we select experimental materials to test this knowledge base.

In summary, SM suffers an object recognition deficit that is more marked for nonliving things—a "category" effect that is present even when familiarity, visual complexity, name frequency and age of acquisition are controlled for. The disorder is unusual both in terms of lesion site (a nonliving-thing disorder after a right-hemisphere lesion) and in terms of its cognitive features. Specifically, SM shows converging evidence of an impairment of stored (though not assembled) structural descriptions, on a variety of tasks of visual and verbal matching, as well as copying and drawing from memory. Current accounts of the relationship between stored knowledge and "category" effects predict that SM should be impaired in the recognition of living things—whereas SM shows the opposite effect. These findings can be re-interpreted in terms of a model in which living things are *less* (rather than more) vulnerable to impairment after

[5]We would like to thank one of the reviewers for suggesting that we develop a measure to quantify this notion and its influence on SM's naming performance.

[6]From Laws and Neve (1999).

[7]This argument is a proposal about the manner in which structural information is organised/represented, such that we would expect to see similar patterns in other patients with disorders that affect their stored knowledge of object structure. In this regard, it is notable that IW, the patient repelled by Lambon Ralph et al. (1998), showed a poorer performance on nonliving things after disruption of his stored knowledge of object structure—i.e. showed the same pattern of deficit as SM.

disruption to stored structural knowledge. To account for these data we have suggested that that one might view nonliving things as having greater within-item structural diversity, and hence they require more structural information in order to be accurately recognised than (more within-item structurally redundant) living things. We have also collected data from normal subject ratings that supports this claim. Moreover, this variable of within-item structural diversity was (unlike so many other "critical" variables) a significant predictor of SM's object recognition performance. These findings suggest a viable mechanism by which one might account for SM's "category" effects in object recognition, in terms of his known deficit in stored knowledge of object structure.

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APPENDIX A

SM's naming of living and nonliving items with different levels of familiarity (after Funnell & Sheridan, 1992)

Living	*Named*	*Nonliving*	*Named*
High familiarity		*High familiarity*	
Cat	1.00	Shirt	1.00
Dog	1.00	Chair	1.00
Arm	1.00	Door	1.00
Ear	.00	Fork	1.00
Eye	.00	Glass	1.00
Foot	1.00	Knife	1.00
Lips	.00	Telephone	1.00
Thumb	1.00	Sun	.00
Mean visual familiarity (*SD*)	3.82 (0.09)		3.69 (0.13)***
Medium Familiarity		*Medium Familiarity*	
Squirrel	1.00	Button	.00
Apple	1.00	Glove	1.00
Banana	.00	Broom	1.00
Carrot	1.00	Couch	.00
Celery	.00	Umbrella	1.00
Cherry	.00	Arrow	.00
Grapes	1.00	Ruler	1.00
Onion	1.00	Hammer	1.00
Pear	.00	Pliers	1.00
Potato	1.00	Scissors	1.00
Tomato	.00	Bike	1.00
Leaf	1.00		
Mean visual familiarity (*SD*)	3.61 (0.16)		3.37 (0.24)**
Low Familiarity		*Low familiarity*	
Donkey	1.00	Thimble	.00
Elephant	1.00	Anchor	.00
Frog	.00	Whistle	.00
Lobster	.00	Accordion	.00
Monkey	1.00	Flute	.00
Mouse	1.00	Harp	.00
Pig	1.00	Axe	1.00
Rhino	1.00	Balloon	.00
Duck	1.00	Kite	.00
Spider	.00	Cannon	.00
Zebra	1.00		
Mean visual familiarity (*SD*)	3.04 (0.35)		2.71 (0.49)*

Visual familiarity significantly different across categories: *p = .05; **p = .01; ***p = .0001; overall p = .04.

APPENDIX B

SM's errors in naming line drawings of living things

	Session 1	*Session 2*	*Session 3*
alligator			
bear			
camel		giraffe	
deer			
eagle		birdie	
elephant			
fox			
frog	don't know	fish	
goat			
gorilla			
kangaroo			
ostrich			
owl			bat
penguin	don't know		birdie
pig			
rhinoceros	mule	water-buffalo	horse
squirrel	rabbit	beastie	rat
zebra			

APPENDIX C

SM's errors in naming line drawings of nonliving things

	Session 1	*Session 2*	*Session 3*
anchor	cross	don't know	to grip things
axe		hammer	
pram	old car	carriage	Queen's carriage
barn	desk	hen house	box
barrel			
basket			
cannon	big logs	gun carrier	log carriage
chisel	don't know	syringe	cigarette holder
cigar	cigarette	cigarette	
clothes-peg	scissors	don't know	don't know
crown	don't know		
gun			
helicopter	windmill		
roller-skate	trailer	tractor-trailer	car frame
spinning-wheel	don't know	don't know	water from ground
well	hut		
windmill			
yacht		don't know	

APPENDIX D

Ratings for within-item structural diversity

Item	*Mean*	*SD*	*Item*	*Mean*	*SD*
accordian	4.15	1.04	celery	4.60	0.75
airplane	3.32	1.11	chain	3.10	1.12
alligator	4.40	0.68	chair	2.68	0.95
anchor	4.40	0.68	cherry	4.60	0.75
ant	4.45	0.69	chicken	4.20	0.77
apple	4.10	0.72	chisel	4.05	0.76
arm	3.79	1.40	church	3.35	0.75
arrow	4.20	1.01	cigar	4.53	0.96
artichoke	4.50	0.61	cigarette	4.85	0.37
ashtray	2.70	1.26	clock	2.65	1.31
asparagus	4.80	0.41	clothespeg	4.26	0.87
axe	4.16	0.69	cloud	3.20	1.06
ball	3.50	1.28	clown	2.95	0.97
balloon	3.35	1.18	coat	2.50	1.19
banana	4.65	0.67	coat hanger	3.95	0.69
barn	3.05	0.94	comb	4.05	1.00
barrel	3.53	1.07	corn	4.35	0.88
baseball	4.35	0.75	couch	2.84	1.07
basket	2.80	1.06	cow	4.00	0.92
bear	3.85	0.81	crash	4.25	0.85
bed	3.00	1.08	crown	3.40	0.99
bee	4.63	0.76	cup	3.10	1.02
beetle	3.50	1.32	deer	4.00	1.12
bell	2.90	1.33	desk	2.95	1.08
belt	3.45	1.00	dog	3.00	1.17
bike	3.50	1.19	doll	2.55	1.23
bird	2.32	1.25	donkey	4.40	0.60
blouse	2.75	1.25	door	3.80	1.15
book	3.25	1.25	doorknob	3.05	1.54
boot	3.20	1.06	dress	2.30	1.08
bottle	2.50	0.95	dresser	3.20	1.06
bow	3.68	1.16	drum	3.40	1.10
bowel	3.15	1.14	duck	4.00	0.97
box	2.90	1.33	eagle	3.90	1.07
bread	3.60	0.88	ear	4.30	1.08
broom	3.65	1.23	elephant	4.80	0.41
brush	3.37	1.07	envelope	4.30	0.98
bus	3.55	1.10	eye	3.89	0.74
butterfly	3.10	1.17	fence	3.50	1.36
button	3.35	1.09	finger	4.50	0.51
cake	1.85	0.99	fish	2.55	1.23
camel	4.47	0.70	flag	2.70	1.30
candle	3.05	0.94	flower	1.84	0.83
cannon	4.45	0.69	flute	4.60	0.50
cap	3.15	1.09	fly	4.25	1.07
car	2.35	1.31	foot	4.35	0.99
carrot	4.53	0.51	football	4.40	0.88
cat	3.10	1.17	fork	4.53	0.96
caterpillar	3.70	0.86	fox	4.20	0.77

APPENDIX D *(continued)*

Item	*Mean*	*SD*	*Item*	*Mean*	*SD*
French horn	4.75	0.44	mouse	4.45	0.60
frog	3.60	1.05	mushroom	3.60	1.31
frying pan	4.05	0.89	nail	3.85	1.35
garbage	3.47	0.96	nail file	3.90	1.07
giraffe	4.74	0.45	necklace	2.60	1.19
glass	3.05	1.43	needle	4.60	0.50
glove	3.90	0.72	nose	4.00	1.21
goat	3.60	1.05	nut	2.90	1.25
go-cart	4.00	0.79	onion	4.50	0.61
gorilla	4.63	0.50	orange	4.60	0.94
grapes	4.20	0.89	ostrich	4.60	0.60
grasshopper	4.35	0.81	owl	3.90	0.79
guitar	3.85	0.75	paintbrush	3.60	1.10
gun	3.00	0.92	pants	3.15	0.93
harp	2.85	1.31	peach	4.64	0.59
hammer	4.40	0.60	peacock	4.60	0.50
hand	4.25	0.79	peanut	4.45	1.00
harp	4.60	0.60	pear	4.40	0.94
hat	2.90	1.25	pen	3.20	1.06
heart	4.55	0.94	pencil	3.70	0.92
helicopter	4.30	0.57	penguin	4.65	0.81
horse	3.95	0.89	pepper	3.95	0.83
house	2.45	1.23	pepper pot	3.40	1.10
iron	3.80	1.06	piano	4.00	0.86
ironing	4.40	0.82	pig	4.50	0.69
jacket	2.90	0.97	pineapple	4.70	0.47
jug	3.45	1.19	pipe	3.45	1.23
jumper	2.45	1.00	pliers	4.35	0.67
kangaroo	4.75	0.44	plug	4.40	0.94
kettle	3.70	0.98	potato	4.30	0.57
key	3.25	1.12	pram	3.50	0.95
kite	3.20	1.32	pumpkin	4.55	0.94
knife	3.60	1.27	rabbit	4.05	0.69
ladder	4.50	0.69	raccoon	4.55	0.69
lamp	3.00	0.92	record player	3.25	1.12
leaf	2.80	1.06	refridge	3.95	0.76
leg	4.25	0.79	rhino	4.75	0.44
lemon	4.80	0.41	ring	2.85	1.39
leopard	4.60	0.60	rocking	3.70	1.03
lettuce	4.30	0.92	roller skate	3.80	0.89
lightswitch	3.55	1.19	rolling	4.40	0.82
lightbulb	4.20	1.11	rooster	4.40	0.75
lion	4.50	0.61	ruler	4.50	0.83
lips	3.75	1.16	sandwich	2.85	0.93
lobster	4.75	0.44	sauce	3.65	1.04
lock	3.30	1.22	saw	4.20	0.95
mitten	4.00	1.03	scissors	4.40	0.68
monkey	3.90	1.21	screw	3.90	1.07
moon	4.50	0.95	screwdriver	3.80	0.95
motorbike	3.45	1.00	sea horse	4.40	0.88
mountain	3.10	1.29	seal	3.95	1.23

APPENDIX D *(continued)*

Item	*Mean*	*SD*	*Item*	*Mean*	*SD*
sheep	4.70	0.47	thumb	4.55	0.69
shirt	3.15	1.31	tie	3.35	1.14
shoe	2.30	1.13	tiger	4.45	0.51
skirt	2.60	1.10	toaster	3.75	0.91
skunk	4.45	0.69	toe	4.50	0.76
sled	3.70	1.13	tomato	4.40	0.60
snail	4.45	0.76	tooth brush	3.90	1.07
snake	3.35	1.14	traffic	4.75	0.55
snowman	3.55	1.05	train	4.05	0.89
sock	3.95	0.60	tree	3.15	1.04
spectacles	3.55	0.94	truck	3.70	1.08
spider	3.90	0.97	trumpet	4.70	0.47
spinning top	4.05	0.94	turtle	4.40	0.82
spinning wheel	3.95	1.05	umbrella	3.80	0.95
spool	4.47	0.61	vase	2.85	1.31
spoon	4.75	0.61	violin	4.35	0.59
squirrel	4.45	0.69	waistcoat	3.70	1.26
star	4.25	1.02	watch	3.00	1.26
stool	3.26	1.33	watering	3.90	0.91
stove	3.70	0.86	watermelon	4.05	0.83
strawberry	4.80	0.52	well	4.55	0.60
suitcase	3.30	1.03	wheel	3.80	1.11
sun	4.60	0.99	whistle	3.65	1.31
swan	4.75	0.55	windmill	4.20	0.95
swing	3.45	1.28	window	3.45	1.05
table	3.45	1.28	wineglass	3.75	1.02
telephone	3.05	1.23	wrench	4.15	0.93
television	3.60	1.19	yacht	3.35	1.14
tennis racket	4.25	0.79	zebra	4.75	0.91
thimble	4.30	1.03			