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Impaired Knowledge of Visual and Non-visual Attributes in a Patient with a Semantic Impairment for Living Entities: A Case of a True Category-specific Deficit

Dana Samson, Agnesa Pillon and **Véronique De Wilde**[1]

Unité de Neuropsychologie cognitive, Université catholique de Louvain and [1]Centre de Revalidation neuropsychologique des Cliniques universitaires Saint-Luc, Louvain-la Neuve, Belgium

Abstract

We report a single case study of a 22-year-old, brain-damaged patient, Jennifer, who showed a semantic deficit affecting living entities (animals and fruit and vegetables) to a greater extent than non-living ones (implements and means of transport). We first show that this category effect was reliable both across time and naming conditions and that it was not an artefact of uncontrolled stimulus factors. We then show that Jennifer had no impairment at the visual or structural processing level and that her deficit was probably located at a semantic processing level. Specific semantic deficits for living entities have usually been explained by damage to the visual semantic system. However, when Jennifer's access to visual and non-visual semantics was assessed through an attribute-verification task, no evidence of an attribute-specific impairment was found: Jennifer was equally impaired in retrieving visual and non-visual attributes of living entities and she was not at all impaired in retrieving visual attributes of non-living entities. Thus, the hypothesis of damage to visual semantics cannot account for the pattern of living things impairment found in this patient. Rather, this pattern seems to require the assumption that the semantic system is organized according to the living/non-living dimension.

Introduction

Over the past decade, there have been numerous reports in the neuropsychological literature of brain-damaged subjects who suffer from a naming impairment selectively affecting one or another semantic category. The most commonly reported pattern of category-specific deficit is the one showing impaired performance in naming and/or recognizing living entities, i.e. animals, vegetables, and fruit, compared to relatively preserved ability to name and/or recognize non-living entities, i.e. transport, implements, and furniture. In a number of cases the category-specific naming deficit could be ascribed to functional damage to semantic memory itself, thus providing a potential source of evidence for the issue of how semantic knowledge is organized and processed in the brain (Warrington and Shallice, 1984; Basso *et al.*, 1988; Silveri and Gainotti, 1988; Farah *et al.*, 1991; Hillis and Caramazza, 1991; Hart and Gordon, 1992; Laiacona *et al.*, 1993, 1997; De Renzi and Lucchelli, 1994; Caramazza and Shelton, 1998). In other cases, the category-specific naming deficit appeared to result from damage to some pre-semantic (e.g. Sartori and Job, 1988; Sheridan and Humphreys, 1993; Arguin *et al.*, 1996; Forde *et al.*, 1997) or post-semantic (e.g. Hart *et al.*, 1985) processes involved in naming. These cases, along with the interpretations that have been proposed to account for their selectivity, will not be discussed in this paper.

Admittedly, selective impairment of the living category might simply reflect differential processing difficulties between living and non-living entities. Items representing living things indeed tend to be of lower frequency and familiarity and more visually complex than items representing non-living things, and these factors are known to have powerful effects on performance in naming and/or recognition tasks. There are thus grounds to cast doubt on the reliability of the category effect reported in studies that did not take into consideration these factors (e.g. Warrington and Shallice, 1984; Basso *et al.*, 1988; De Renzi and Lucchelli, 1994). The category effect indeed turned out to disappear, in some cases, when the two categories were matched for frequency, familiarity, and visual complexity (Funnell and Sheridan, 1992; Stewart *et al.*, 1992). Nonetheless, a substantial number of cases with selective

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Correspondence to: Dana Samson, Unité de Neuropsychologie cognitive (NECO), Faculté de psychologie et des sciences de l'éducation, Université catholique de Louvain, place du Cardinal Mercier 10, B-1348 Louvain-la-Neuve, Belgium. e-mail: samson@neco.ucl.ac.be

impairment for living entities still showed the category effect when these three factors were controlled (Hart and Gordon, 1992; Laiacona *et al.*, 1993, 1997; Farah *et al.*, 1996; Funnell and De Mornay Davies, 1996; Gainotti and Silveri, 1996; Caramazza and Shelton, 1998). Furthermore, a few cases showing the reverse pattern of dissociation—a semantic impairment affecting selectively *non-living* entities—have also been reported (Warrington and McCarthy, 1983, 1987; Hillis and Caramazza, 1991; Sacchett and Humphreys, 1992), which seriously undermines processing complexity accounts of category-specific impairments.

Which organizing principle of the semantic memory or which processing principle could be responsible for patterns of deficits conforming to the living/non-living distinction? The apparently simplest answer to this question would be that the living/non-living distinction simply represents a fundamental organizing principle of the semantic memory (Warrington, 1981). However, such a direct inference has aroused general scepticism and, until very recently (Caramazza and Shelton, 1998), the hypothesis of a categorical organization of semantic memory along the living/non-living dimension has not been seriously explored.

Instead, since the very beginning of the study of category-specific deficits, the dominant view has been that category effects emerged as an accidental consequence of another organizing principle of the semantic system: the nature or type of information being represented. According to this view, the set of perceptual (i.e. visual, tactile, and auditory), functional and associative attributes that jointly represent the knowledge of an object—its semantic representation—is stored across distinct semantic subsystems, each specialized in representing one kind of information—visual, tactile, functional, etc. (Warrington and McCarthy, 1983, 1987; Warrington and Shallice, 1984; Shallice, 1988; Farah and McClelland, 1991). In particular, the theory assumes that visual properties that are part of an object's meaning are represented and processed by a specialized *visual* semantic system which, therefore, has to be distinguished from a pre-semantic system processing high-level perceptual, i.e. structural, information from the visually presented object (see Hillis and Caramazza, 1996, for the empirical basis of a theoretical distinction between structural and semantic representations of an object's visual properties). In that way, brain damage can selectively destroy visual semantic attributes by leaving the others relatively spared. A specific category deficit arises, in such a context, from the differential weight of each kind of attribute in representing knowledge of the various categories of objects. It is assumed that living things are defined primarily by their sensory (mainly visual) attributes, whereas non-living things are defined primarily by their functional attributes. Thus, according to this hypothesis, the putative living/non-living dissociations are to be viewed as sensory/functional dissociations: a semantic deficit, selectively or disproportionately affecting, say, living entities, accidentally arises in fact from damage to the visual (sensory) semantic subsystem.

The sensory–functional account of category-specific deficits has two main implications. First, it predicts that cases of living things impairment should show poorer knowledge of the visual attributes than the functional attributes of living things. Given that most of the semantic attributes of living things, i.e. their visual attributes, would be destroyed, then their few functional attributes might lack the critical mass to become activated (see the computational variant of the hypothesis, proposed by Farah and McClelland, 1991). So damage to the visual semantic subsystem is expected to affect retrieval of the functional attributes of living things as well, but to a lesser extent. This prediction has been confirmed in several studies which have attempted to distinguish knowledge of visual or sensory properties from knowledge of functional ones (Basso *et al.*, 1988; Farah *et al.*, 1989; Hart and Gordon, 1992; De Renzi and Lucchelli, 1994; Powell and Davidoff, 1995; Gainotti and Silveri, 1996). The different types of knowledge were assessed by asking, for instance, the patient to answer questions probing either sensory–visual or functional properties. Thus Farah *et al.* (1989) found that their patient, LH, was 63% correct when he had to respond to questions probing visual attributes of living objects (e.g. 'Are the hind legs of a kangaroo larger than the forelegs?'), while he was 85% correct for questions probing their functional attributes (e.g. 'Are roses given on Valentine's day?'). Another task that was commonly used consisted in asking the patient to name an object from a verbal description of either its visual or non-visual properties. In such a task, patient LA (Gainotti and Silveri, 1996) correctly named 6% of the living objects from their visual description (e.g. 'It is a small animal with a sharp nose, long whiskers and a long, thin tail') and 43% of them from their functional description (e.g. 'It is an animal called the ship of the desert, that can live for long periods without drinking'). There are, however, some cases of category-specific deficit for living things that do not show the predicted pattern: in these cases, processing visual and functional attributes for living things appeared equally impaired (Laiacona *et al.*, 1993, 1997; Caramazza and Shelton, 1998). Thus, in a multiple-choice question task, GR, one of the patients reported by Laiacona *et al.* (1993), scored 55% when visual attributes of living things were probed (e.g. 'Is an apple round, oblong or conical?') and 58% when functional attributes were probed (e.g. 'Do we eat an apple raw, dried or in both ways?'). Funnel and De Mornay Davies (1996), in a new analysis of JBR (Warrington and Shallice, 1984), also found equal level of performance in an attribute-verification task for visual and functional attributes. However, the import of this result is obscured by the patient performing equally for living and non-living things in the attribute-verification task. In fact, the patient did not appear impaired in verifying visual and functional attributes, either for living or for non-living things.

A further implication of the sensory–functional account of category-specific deficits is that patients with a living-things impairment should also perform below normal range in processing visual attributes of non-living things: if the category-specific deficit merely reflects damage to a visual semantic subsystem, shared by both living and non-living categories, then the visual attributes of non-living things should not be totally spared. The sensory–functional hypothesis does not seem to predict that visual attributes should be as impaired for non-living as for living things when the visual semantic subsystem is damaged. Non-living things are assumed to be defined predominantly by their functional attributes. If functional semantics is spared, most of the semantic properties in the representation of non-living things would be retrieved, and this might act as a sufficient mass effect for at least some of their visual properties being retrieved. However, the hypothesis, as well as its computational variant (Farah and McClelland, 1991), does not allow us to derive a more precise expectation as to the degree of impairment that would affect the visual attributes of non-living things when the visual semantic subsystem is impaired. No result pertaining to this aspect of the model is provided from the simulations of damage to the visual semantic units in the Farah and McClelland study. In phrasing the second prediction of the model, we thus confine ourselves cautiously to expect processing of visual attributes to be not entirely normal for non-living things. Evidence pertaining to this point is not available in some case reports (e.g. Basso *et al.*, 1988) and, when evidence is available, it appears rather contradictory: depending on the case report, visual knowledge for non-living objects was totally spared (Hart and Gordon, 1992; Laiacona *et al.*, 1993, 1997; De Renzi and Lucchelli, 1994) or moderately impaired (Powell and Davidoff, 1995; Gainotti and Silveri, 1996).

It thus appears that several cases of patients with selective damage to the living category do not fit perfectly into the pattern of performance predicted by the sensory–functional account of category-specific deficits. In this paper, an additional case of living-things impairment is reported, which contradicts both predictions mentioned above: the patient Jennifer showed equally poor knowledge of the visual and the functional attributes of living things, and normal knowledge of the visual and the functional attributes of non-living things. After a brief case report and the description of the general methodology of the experimental study, the results will be presented and organized as follows. First, we show that the pattern of living/non-living dissociation Jennifer presented in naming tasks is reliable both across time and naming conditions, and that this pattern is not an artefact of uncontrolled stimulus factors. We then show that there is no evidence that Jennifer suffers from a visual or structural processing impairment and that her naming deficit is probably to be located at a more central, semantic, processing level. Finally, we show that in an attribute-verification task, Jennifer's performance is equally impaired for the visual and the functional attributes of living things, while being within normal range for both types of attributes when non-living things are probed. In the General discussion, we review the implications of these results for the sensory–functional account of category-specific deficits and discuss alternative accounts.

Case report

Jennifer is a 22-year-old, right-handed woman of Moroccan origin who had 8 years of formal education, all pursued in French. In August 1992, when she was 19, she had a car accident and was severely injured. A CT scan, performed in March 1994 (19 months post-onset), revealed significant atrophy of the posterior part of the left hemisphere with a compensatory dilatation of the posterior horn of the lateral ventricle. It also revealed a hypodensity in the left frontal paramedian region. Since an osteosynthesis metallic material was present at the cervical level, a cerebral MRI could not be performed.

Two months post-onset, the patient was submitted to a neuropsychological examination, but no precise diagnosis could be achieved as the patient was in a strong confusional state. Jennifer was then referred to several rehabilitation centres before she was again admitted to the Cliniques universitaires Saint-Luc, in February 1995. At that time, the medical examination showed a right homonymous hemianopsy (non-compensated) and a right crural monoplegia. The neuropsychological exams essentially revealed language and memory impairments.

In short-term memory tasks, Jennifer's performance was slightly below normal range. Her digit span was 5 (control = 7) and her spatial span, measured with a block-tapping test, was 4 (control = 5–6). However, Jennifer showed severe impairment in visual long-term memory tasks. On the Doors Test (Baddeley *et al.*, 1994), she scored 1/12 (controls = 11.6/12) on the first and easiest part of the test. Verbal long-term memory, assessed with Grober and Buschke's test (Grober and Buschke, 1987), was also severely impaired. On the first presentation, Jennifer recalled 2/16 items in the free recall condition (control = 9.6) and two additional items in the cued recall condition (control = 5.2). On the second presentation, Jennifer recalled 1/16 items in the free recall condition (control = 11.6) and four additional items in the cued recall condition (control = 3.9). On the third presentation, Jennifer performed 2/16 in the free recall condition (control = 13.5) and recalled nine additional items in the cued condition (control = 2.3). After a 20 min delay, Jennifer scored 1/16 in free recall (control = 13.9) and recalled 10 additional items in the cued recall condition (control = 2).

The extensive language screening was performed with the Batterie d'évaluation du langage (Cliniques universitaires St-Luc), which comprises a large set of subtests aiming at assessing sublexical, lexical, semantic and morpho–syntactic processing in the different speech modalities. This screening essentially revealed naming, reading, and writing difficulties. Difficulties in reading and writing irregular words suggested both a surface dyslexia and a surface dysgraphia. Naming, further investigated with the Snodgrass and Vanderwart (1980)'s pictures, was poor (166/260, 64%), particularly for items belonging to the category of natural objects, i.e. animals, fruit and vegetables, body parts, and natural elements. She scored 44/100 (44%) for natural objects, and 122/160 (76%) for man-made objects. This natural/man-made dissociation was not due to uncontrolled factors such as word frequency, concept familiarity and visual complexity. A logistic regression analysis with Jennifer's accuracy as the dependent variable and category, word frequency (Content *et al.*, 1990), concept familiarity (Snodgrass and Vanderwart's rating), and visual complexity (Snodgrass and Vanderwart's rating) as the independent variables, revealed a highly significant effect of category once the three other independent variables were adjusted for ($\chi^2 = 15.4$, $P < 0.001$). However, spoken word comprehension was good, for concrete (all inanimate) as well as for abstract words. Jennifer performed very well at a short version of the Batterie d'examen des mots concrets et abstraits (Samson and Pillon, unpublished). She scored 46/48 in the auditory lexical decision task and 21/24 in the auditory synonym-verification task (all errors were made on low frequency words and consisted in accepting a close semantic associate as the synonym of the probed word).

Neuropsychological examination identified no other serious defect. Jennifer's scores were within normal range for all the tasks of the BORB (Birmingham Object Recognition Battery; Riddoch and Humphreys, 1993), except the overlapping figures task (task 6), where she made errors which can be attributed to her naming deficit, and in the object decision task, where she performed slightly below norms (Jennifer: 99/128, norms available: mean = 114.7/128, SD = 5.7, range = 106–124). Although there were indications of frontal disorders in her social behaviour, no pathological signs were evidenced by formal testing of frontal functions.

Experimental study

General methodology

Materials

In this experimental study, a number of tasks were prepared in order to assess the patient's naming abilities (oral picture naming, written picture naming and oral naming from verbal description tasks), as well as her pre-semantic (object decision and auditory lexical decision tasks) and semantic processing abilities (categorization, size judgement, word/picture verification, and verbal description tasks) in conditions that do not require the object's name retrieval. In order to avoid the ambiguities due to different items being used across the various tasks, we chose to use the same 72 items in all the tasks except for the object decision task, where only a subset of these 72 experimental items were used, in addition to new items. The underlying methodological reasons for this change are described further. Half of the items (36) corresponded to living entities (18 animals and 18 fruit and vegetables), the other half to non-living entities (18 implements and 18 means of transport). The complete list of items is presented in Appendix A. The pictures corresponding to these items were drawn in a similar style and were issued from a CD-ROM database (Corel Corporation©, 1994). These pictures, originally coloured, were printed on cards in grey levels. The 72 pictures were presented in a booklet, one picture per sheet, to a group of 15 normal subjects who were asked to rate their visual complexity on a five-point scale. The mean visual complexity of the pictures was 2.86 for the living items and 2.93 for the non-living items, a non-significant difference [$t(70) = 0.32$, $P > 0.7$]. Another group of 15 normal subjects was presented with the same pictures and asked to rate on a five-point scale how familiar the concept depicted in the picture was to them. The mean concept familiarity was 2.65 and 2.96 for the living and non-living items respectively, again a non-significant difference [$t(70) = 1.26$, $P > 0.2$]. For both ratings, subjects were given the same instructions as those used by Snodgrass *et al.*, 1980. The mean word frequency was 839 and 1582 per 100×10^6 (Content *et al.*, 1990) for the living and non-living items respectively, a difference that was not significant [$t(61.3) = 1.1$, $P > 0.2$]. The mean values of visual complexity, concept familiarity, and word frequency for each of the four subcategories of items, together with the results of all statistical comparisons between them, are displayed in Table 1.

Control subjects

All the tasks were presented to a control group. This group, a pool of eight normal subjects, matched to the patient for age (mean age = 20 years), gender, ethnic group (all were of Moroccan origin and pursued their scholarship in French), and education level (mean number of years of scholarship = 9; range 7–12). Each task was presented to four of the control subjects, except for the written naming task, which was only presented to three controls because of the withdrawal of one subject during this study. The oral and the written version of the picture naming task were not presented to the same subject.

Experimental procedure

The experimental study has been carried out from September, 1995 to July, 1996 in several sessions of 30–40 min each. Jennifer was presented first with all the tasks requiring a word output, i.e. the oral picture naming, the written picture naming, and the oral naming to description, tasks. A period of at least 1 week was given between each of these naming tasks. Jennifer was then presented with the

Table 1. t-Test comparisons between the four semantic categories for visual complexity, concept familiarity and word frequency

	Visual complexity			
	Animals Mean = 3.55	Fruit and vegetables Mean = 2.16	Implements Mean = 2.34	Transport Mean = 3.51
Animals Mean = 3.55	—	t (34) = 7.06, $P < 0.001$	t (27.2) = 5.25, $P < 0.001$	t (34) = 0.22, $P > 0.8$
Fruit and vegetables Mean = 2.16		—	t (34) = 0.71, $P > 0.4$	t (34) = 6.43, $P < 0.001$
Implements Mean = 2.34			—	t (34) = 4.84, $P < 0.001$
Transport Mean = 3.51				—
	Concept familiarity			
	Animals Mean = 1.65	Fruit and vegetables Mean = 3.64	Implements Mean = 3.35	Transport Mean = 2.57
Animals Mean = 1.65	—	t (34) = 11.04, $P < 0.001$	t (25.1) = 6.26, $P < 0.001$	t (27.1) = 3.77, $P < 0.001$
Fruit and vegetables Mean = 3.64		—	t (26.2) = 1.03, $P > 0.3$	t (34) = 4.21, $P < 0.001$
Implements Mean = 3.35			—	t (34) = 2.39, $P < 0.03$
Transport Mean = 2.57				—
	Word frequency			
	Animals Mean = 1249	Fruit and vegetables Mean = 430	Implements Mean = 648	Transport Mean = 2516
Animals Mean = 1249	—	t (18.8) = 1.09, $P > 0.2$	t (20) = 0.78, $P > 0.4$	t (34) = 0.98, $P > 0.3$
Fruit and vegetables Mean = 430		—	t (34) = 0.79, $P > 0.4$	t (17.9) = 1.9, $P > 0.06$
Implements Mean = 648			—	t (18.4) = 1.72, $P > 0.1$
Transport Mean = 2516				—

tasks assessing word and picture understanding in the following order: (1) auditory lexical decision; (2) semantic categorization; (3) verbal description of an object from its name; (4) word–picture verification; (5) object decision. The oral picture naming task was then presented twice again to the patient, with a period of 2 weeks given between both presentations. The study ended with the attribute-verification task.

Assessing the consistency and the reliability of the living/non-living dissociation in naming

Method

Jennifer was asked to name the 72 experimental items in three conditions: oral picture naming, written picture naming, and oral naming from a verbal description provided by the examiner. The verbal description provided information about the category membership of the target, its physical appearance and functional properties, as well as encyclopaedic information (e.g. for kangaroo: 'it is a big animal with four legs, his coat is usually reddish-brown, its hind legs are more developed than the forelegs, and the females have a pouch on their stomachs in which their babies grow, it lives in Australia and moves forward by jumping'; for saw: 'it is an object made of a grip and a big long blade with sharp teeth, it is used for cutting wood by pushing by hand backwards and forwards'). The oral picture naming task was presented three times, with a period of 7 months given between the first and the second presentation, and a period of 2 weeks between the second and third.

Results

Jennifer's and the control group's scores in the different naming conditions are summarized in Table 2. Jennifer's errors consisted mostly in semantic errors and non-responses for living entities, and in semantic errors for non-living entities (see Table 3 for the distribution of the different kinds of errors in the three naming tasks).

Table 2. Number and percentage of Jennifer and controls' correct naming responses in the three naming conditions and the three presentations of the oral picture naming task

	Jennifer								
	First presentation		Second presentation		Third presentation		Controls		
	n	(%)	*n*	(%)	*n*	(%)	Mean	(%)	Range
Oral picture naming task									
Animals	4/18	(22.2%)	3/18	(16.7%)	4/18	(22.2%)	17/18	(94.4%)	16–18
Fruit and vegetables	9/18	(50%)	10/18	(55.6%)	10/18	(55.6%)	15.5/18	(86.1%)	12–18
Living entities (total)	13/36	(36.1%)	13/36	(36.1%)	14/36	(38.9%)	32.5/36	(90.3%)	28–36
Implements	14/18	(77.8%)	15/18	(83.3%)	12/18	(66.7%)	15/18	(83.3%)	13–16
Transport	14/18	(77.8%)	14/18	(77.8%)	13/18	(72.2%)	15.5/18	(86.1%)	14–17
Non-living entities (total)	28/36	(77.8%)	29/36	(80.6%)	25/36	(69.4%)	30.5/36	(84.7%)	27–33
Written picture naming task									
Animals	4/18	(22.2%)	—	—	—	—	17/18	(94.4%)	16–18
Fruit and vegetables	9/18	(50%)	—	—	—	—	16.7/18	(92.8%)	15–18
Living entities (total)	13/36	(36.1%)	—	—	—	—	33.7/36	(93.6%)	33–35
Implements	12/18	(66.7%)	—	—	—	—	16/18	(88.9%)	16–16
Transport	14/18	(77.8%)	—	—	—	—	16/18	(88.9%)	16–16
Non-living entities (total)	26/36	(72.2%)	—	—	—	—	32/36	(88.9%)	32–32
Oral naming to description task									
Animals	5/18	(27.8%)	—	—	—	—	14.5/18	(80.6%)	13–18
Fruit and vegetables	8/18	(44.4%)	—	—	—	—	14/18	(77.8%)	12–16
Living entities (total)	13/36	(36.1%)	—	—	—	—	28.5/36	(79.2%)	27–34
Implements	9/18	(50%)	—	—	—	—	13.75/18	(76.4%)	12–15
Transport	15/18	(83.3%)	—	—	—	—	15.5/18	(86.1%)	15–17
Non-living entities (total)	24/36	(66.7%)	—	—	—	—	29.25/36	(81.3%)	27–30

Jennifer appeared clearly impaired in naming living entities, while her performance for non-living entities fell within or just below the normal range. This pattern of dissociation between living and non-living items is present in all three examinations and all three naming conditions.

In order to ensure that the living/non-living dissociation in Jennifer's performance was not due to uncontrolled stimulus factors, the data were entered into a logistic regression analysis with response accuracy as the dependent variable, and category membership (living versus non-living) and three additional factors, i.e. word frequency, concept familiarity and visual complexity, as the independent variables. The picture's visual complexity was not taken into consideration for the results of the naming to verbal description task. The results revealed that word frequency and visual complexity did not appear to have a significant effect on performance in any of the naming conditions ($0.2 < \chi^2 < 2.7$; $0.1 < P < 0.7$), while concept familiarity had a significant effect in all the conditions (oral picture naming: $\chi^2 = 12.3$, $P < 0.001$; written picture naming: $\chi^2 = 7.9$, $P < 0.005$; oral naming to verbal description: $\chi^2 = 9.3$, $P < 0.003$). Nevertheless, naming performance appeared to be significantly worse for living than non-living entities once frequency, concept familiarity and visual complexity were accounted for (oral picture naming, first presentation: $\chi^2 = 10.8$, $P < 0.001$; written picture naming: $\chi^2 = 6.8$, $P < 0.01$; naming to verbal description: $\chi^2 = 4.7$, $P < 0.03$). Thus, whereas concept familiarity had a powerful influence on naming performance, it cannot account by itself for the category effect. We also performed a logistic regression analysis by entering, as the dependent variable the number of items that was correctly named at the first, second and third presentation as well (oral picture naming task) and, as independent variables, the same factors as in the previous analysis. The results of this analysis revealed a highly reliable category effect ($\chi^2 = 26.4$, $P < 0.0001$).

Two additional features of the living/non-living dissociation in Jennifer's naming performance are worth noting. First, the living/non-living dissociation was not confined to items of low frequency. As can be seen in Table 4, where the items were split into low-familiarity (familiarity rating < 2.5) and high-familiarity (≥ 2.5) items, high-familiarity items in the living category gave rise to worse performance than high-familiarity items in the non-living category. Second, there was no evidence of a further dissociation within the living category. The outcome of a logistic regression performed as above, but with category membership having four levels (animals/fruit and vegetables/implements/transport) instead of two (living/non-living), indicated that, once visual complexity, concept familiarity and word frequency were accounted for, performance for animals was not significantly more impaired than that for fruit and vegetables, whatever the naming condition considered (oral picture naming: $\chi^2 < 1$; written picture naming: $\chi^2 < 1$; naming to verbal description: $\chi^2 = 2.5$, $P < 0.1$). Jennifer's performance in the two non-living subcategories (transports and implements) did not significantly differ, either, at least as far as the oral and the written picture naming tasks are concerned ($\chi^2 < 1$). In the naming to verbal description task, transport were better

Table 3. Number and percentage of different kinds of naming errors made by Jennifer to living and non-living items across the different naming conditions

	Animals	Fruit and vegetables	Total for living items	Implements	Transport	Total for non-living items
Oral picture naming task						
Semantic	4/14 (28.6%)	5/9 (55.6%)	9/23 (39.1%)	4/4 (100%)	3/4 (75%)	7/8 (87.5%)
Non-response	6/14 (42.8%)	3/9 (33.3%)	9/23 (39.1%)	—	—	—
Visual	—	—	—	—	1/4 (25%)	1/8 (12.5%)
Superordinate	4/14 (28.6%)	—	4/23 (17.4%)	—	—	—
Circumlocutions and/or comments	—	1/9 (11.1%)	1/23 (4.4%)	—	—	—
Written picture naming task						
Semantic	1/14 (7.2%)	6/9 (66.7%)	7/23 (30.4%)	5/6 (83.3%)	2/4 (50%)	7/10 (70%)
Non-response	10/14 (71.4%)	2/9 (22.2%)	12/23 (52.2%)	1/6 (16.7%)	—	1/10 (10%)
Visual	—	—	—	—	1/4 (25%)	1/10 (10%)
Superordinate	3/14 (21.4%)	1/9 (11.1%)	4/23 (17.4%)	—	—	—
Circumlocutions and/or comments	—	—	—	—	1/4 (25%)	1/10 (10%)
Oral naming to description task						
Semantic	7/13 (53.8%)	7/10 (70%)	14/23 (60.9%)	9/9 (100%)	1/3 (33.3%)	10/12 (83.4%)
Non-response	6/13 (46.2%)	3/10 (30%)	9/23 (39.1%)	—	1/3 (33.3%)	1/12 (8.3%)
Visual	—	—	—	—	—	—
Superordinate	—	—	—	—	1/3 (33.3%)	1/12 (8.3%)
Circumlocutions and/or comments	—	—	—	—	—	—

Table 4. Number and percentage of Jennifer's correct responses on naming high- and low-familiarity items across the three naming conditions

	High-familiarity items			Low-familiarity items		
	Jennifer *n* (%)	Controls *n* (%)	Range	Jennifer *n* (%)	Controls *n* (%)	Range
Oral picture naming task						
Living entities	10/19 (52.3%)	16.5/19 (86.8%)	13–19	3/17 (17.6%)	16/17 (94.1%)	15–17
Non-living entities	22/25 (88%)	22.3/25 (89.2%)	19–24	6/11 (54.5%)	8.3/11 (75.4%)	7–9
Written picture naming task						
Living entities	10/19 (52.6%)	17.7/19 (93.2%)	16–19	3/17 (17.6%)	16/17 (94.1%)	15–17
Non-living entities	20/25 (80%)	22.3/25 (89.2%)	22–23	6/11 (54.5%)	9.7/11 (88.2%)	9–10
Oral naming to description task						
Living entities	9/19 (47.4%)	15/19 (78.9%)	13–17	4/17 (23.5%)	13.5/17 (79.4%)	12–17
Non-living entities	19/25 (76%)	21/25 (84%)	20–22	5/11 (45.5%)	8.5/11 (77.3%)	6–10

named than implements ($\chi^2 = 10$, $P < 0.002$), a pattern of performance that was also noted, however, in the control subjects. This difference might be due to the verbal labels used for referring to features (particularly, visual features) defining transport (e.g. 'wheels', 'propellers', etc.) being more familiar than those used for referring to implements (e.g. 'long metal rod', 'rolled up band', etc.).

Finally, the consistency of Jennifer's performance across the three presentations of the oral picture naming task was assessed by comparing, for each individual item, the accuracy of her response at the first and second presentation, on one hand, and at the first and third presentation, on the other. The rate of consistent responses (both correct or both wrong) was 88% between the first and the second presentation (89% for living entities and 86% for non-living entities); it was 86% between the first and third presentation (same rate for both living and non-living entities). This corresponds to a very high degree of consistency (rphi = 0.74 and 0.72 for the first/second and first/third comparisons, respectively). Response consistency across the naming conditions was also assessed by comparing the accuracy of Jennifer's naming response for each individual item across the two input modalities (picture naming versus naming to verbal description) on the one hand, and across the two output modalities (oral picture naming versus written picture naming) on the other. The rate of consistent responses (both correct or both wrong) was 81% (83% for living entities and 78% for non-living entities) between the oral picture naming and the oral naming on verbal description tasks (rphi = 0.61). Between the oral and written picture naming, it was 89% (94% for living entities and 83% for non-living entities), a very high degree of consistency (rphi = 0.77).

The analysis reported above showed that concept familiarity had a significant effect on Jennifer's naming performance. The question, then, is whether the high degree of consistency in Jennifer's responses across time and naming conditions remains significant when compared to that which would be predicted on the basis of concept familiarity alone. We applied the procedure used by Howard (1995), in order to predict the number of items that would be correctly named on zero, one, two or three presentations, in zero, one or two input modalities, and in zero, one or two output modalities, if (1) the probability of correct naming was equal for all items (chance) and (2) the probability of correct naming was a linear function of concept familiarity (see Howard, 1995, pp. 1008–1009, for details about the statistical procedure). The results of this procedure are summarized in Table 5. The analysis revealed that the number of items that were correctly named on the three presentations, in the two input, and in the two output modalities, is significantly higher than that which is expected if item consistency was due to chance or to concept familiarity alone.

Table 5. Consistency of Jennifer's responses across time and naming conditions, as assessed against two different null hypothesis

No. of times correct	No. of items	Predicted by	
		Chance	Familiarity
Consistency across three presentations of the oral picture naming task			
0	24	6.2	11
1	9	23.4	20
2	4	29.8	21
3	35	12.6	20
		$\chi^2(3) = 122.1$ $P < 0.001$	$\chi^2(3) = 46.4$ $P < 0.001$
Consistency across naming to a picture versus to a description			
0	27	15.9	18.4
1	14	35.9	31.2
2	31	20.2	22.4
		$\chi^2(2) = 26.9$ $P < 0.001$	$\chi^2(2) = 16.8$ $P < 0.001$
Consistency across oral versus written picture naming			
0	28	13.9	17.8
1	8	35.5	28.3
2	36	22.6	25.9
		$\chi^2(2) = 43.6$ $P < 0.001$	$\chi^2(2) = 24.3$ $P < 0.001$

Note: hypothesis 1: the probability of correct response is equal for all items (chance); hypothesis 2: the probability of correct response is a linear function of concept familiarity.

Discussion

Jennifer's naming performance appeared to be strongly influenced by concept familiarity. However, when this factor, as well as word frequency and visual complexity, was controlled for, the patient still showed a highly reliable category effect. This category effect turned out to be very consistent across time and input/output modalities. Moreover, a high degree of item-consistency was found across presentations and naming conditions. All this suggests that the locus of the deficit causing the naming difficulties is probably not at a pre-semantic, visual or structural, processing level: Jennifer was equally impaired when she had to name from a picture or from a verbal description, and her naming difficulties arose (generally) from the same items in both tasks. The underlying deficit is probably not to be located at a post-semantic (e.g. phonological) processing level either: Jennifer was equally impaired when she had to produce orally or to write down the name of the picture and, here again, her naming difficulties arose (generally) from the same items in both modalities. The experiments presented in the following section aimed at confirming this hypothesis about the damaged processing level causing the naming impairment.

Identifying the locus of the naming impairment

Assessing pre-semantic processing levels

Object decision task: Since Jennifer's performance at the object decision task of the BORB (Riddoch and Humphreys, 1993) appeared slightly below the published norms (see Case report), mild damage to the structural processing level could not be dismissed at this stage. Moreover, the items comprised in the BORB did not allow an appropriate comparison of performance in the four categories of items selected in the naming tasks (living: animals and fruit and vegetables; non-living: implements and transport). In order to assess further the patient's structural processing abilities, another object decision task, that included items drawn from these four categories, was prepared. Since the patient had already been presented with the 72 experimental pictures in the picture naming tasks, another set of pictures was selected for this object decision task: if the same

Table 6. Number and percentage of Jennifer and controls' correct responses in the finer-grained categorization tasks of pictures and words

	Jennifer		Controls		
	n	(%)	Mean	(%)	Range
Picture categorization task					
Animals	16/18	(88.9%)	13.25/18	(73.6%)	12–14
Fruit and vegetables	18/18	(100%)	18/18	(100%)	18–18
Living entities (total)	34/36	(94.4%)	31.25/36	(86.8%)	30–32
Implements	18/18	(100%)	18/18	(100%)	18–18
Transport	18/18	(100%)	18/18	(100%)	18–18
Non-living entities (total)	36/36	(100%)	36/36	(100%)	36–36
Word categorization task					
Animals	15/18	(83.3%)	14.5/18	(80.6%)	14–15
Fruit and vegetables	17/18	(94.4%)	17.25/18	(95.8%)	17–18
Living entities (total)	32/36	(88.9%)	31.75/36	(88.2%)	31–32
Implements	17/18	(94.4%)	17.25/18	(95.8%)	17–18
Transport	18/18	(100%)	17.25/18	(95.8%)	16–18
Non-living entities (total)	35/36	(97.2%)	34.5/36	(95.8%)	33–36

pictures were used for object decision, the patient could classify the pictures of real objects as such merely on the basis of her feeling of familiarity with these pictures she had seen previously. Thus, to avoid this potential bias, two precautions were taken: (1) among the 72 experimental items composing the naming task, only one-half (nine out of each of the four categories) were selected again for the object decision, the other half being new items; (2) this new set of 72 items was all drawn in a style similar to the one used by Snodgrass and Vanderwart (while the pictures used in the naming tasks were all drawn in a fine grained drawing style and printed in grey levels). Half of the pictures of each category were used just as they were to constitute the set of real objects. Unreal object pictures were made up with the other half, by combining parts of two pictures belonging to the same category (see Appendix B for examples). Jennifer was presented the pictures in a random order and was asked to say, for each picture, if she recognized the entity depicted in the drawing as something that exists in real life. She performed quite well in this task, as she scored 65/72 (mean for the control group = 68/72; range 65–72). Her errors consisted both of rejecting real objects and accepting unreal objects; they were equally distributed across the four semantic categories.

Auditory lexical decision task: A total of 72 words and 72 pseudowords was auditorily presented in random order to Jennifer, who was asked to tell whether the stimulus was a word or not. All the words corresponded to the experimental items. The pseudowords were constructed by changing one phoneme at the beginning, in the middle or at the end of an existing word so that they conformed to the French phonotactics. The words from which the pseudowords were made up were selected, in equal number, from the four semantic categories; they were matched for frequency and word length to the experimental items. Jennifer responded quickly and accurately in this task: her responses were 100% correct.

Comment: The results of the object and lexical decision task indicated that the pre-semantic processing levels involved in picture and spoken word comprehension were spared. This allows us to rule out an influence of pre-semantic difficulties in the tasks presented in the next two sections, which aimed to assess Jennifer's semantic processing abilities by using spoken words and/or pictures as input stimuli.

Assessing the semantic processing level

Jennifer's semantic processing abilities have been assessed through three tasks that we assumed would tap various aspects of the semantic knowledge: categorial and subcategorial knowledge (categorization tasks), knowledge of a general physical attribute (size judgement task) and specific semantic knowledge, i.e. knowledge that allows the differentiation between the members of a given category (picture–word verification task with close semantic foils and object's verbal description task).

Categorization tasks: Jennifer was presented with the 72 experimental items in a random order, as picture stimuli in one session, and as spoken word stimuli, in another session. She was first asked to classify them into four broad semantic categories: animals, vegetables, implements, and means of transport. Once she achieved this task, she was given the items of each category separately and asked to sort them into finer-grained categories: animals into the ones who live in foreign countries and those who live in Belgium; vegetables into fruit and vegetables; implements into tools (carpenter's or gardening tools) and office implements; and transport into sea, air or surface transportation. Jennifer made no errors when asked to classify pictures or words into one of the four broad semantic categories. She performed within normal range (see Table 6) in the finer-grained categorization task, for living as well as for non-living items, and for pictures as well as for word stimuli.

Table 7. Number and percentage of Jennifer's and controls' correct responses in the word/picture verification task

	Jennifer		Controls		
	n	(%)	Mean	(%)	Range
Animals	8/18	(44.4%)	16.25/18	(90.3%)	15–18
Fruit and vegetables	13/18	(72.2%)	17/18	(94.4%)	15–18
Living entities (total)	21/36	(58.3%)	33.25/36	(92.4%)	30–35
Implements	13/18	(72.2%)	16.25/18	(90.3%)	15–18
Transport	13/18	(72.2%)	15.25/18	(84.7%)	12–17
Non-living entities (total)	26/36	(72.2%)	31.5/36	(87.5%)	28–34

Table 8. Number and percentage of Jennifer's and controls' verbal descriptions of objects that were recognized by at least two judges

	Jennifer		Controls		
	n	(%)	Mean	(%)	Range
Animals	8/18	(44.4%)	12.5/18	(69.4%)	11–14
Fruit and vegetables	7/18	(38.9%)	11.25/18	(62.5%)	7–14
Living entities (total)	15/36	(41.7%)	23.75/36	(66%)	18–28
Implements	12/18	(66.7%)	12.25/18	(68.1%)	11–14
Transport	15/18	(83.3%)	13.75/18	(76.4%)	12–17
Non-living entities (total)	27/36	(75%)	26/36	(72.2%)	23–30

Size judgement task: The 72 experimental items were used to construct 36 pairs of words, with the two words in a pair belonging to the same category. Jennifer was asked to decide which item of the pair was bigger in size. This task was presented a second time two months after the first presentation. Jennifer made only one error each time, the same error in both presentations (a potato judged bigger than a leek).

Word–picture verification task: Jennifer was given each picture of our experimental set simultaneously with a spoken word. She was asked to tell if the word was the correct name for the pictured object. Each picture was presented once with the correct word, once with a word that was a 'close' co-ordinate of the correct word and once with a word that was a 'far' co-ordinate of the correct word (no picture was presented twice in the same session). For instance, the picture of a donkey was presented once with the word 'donkey', once with the word 'horse' and once with the word 'hippopotamus'. An item was scored as correct when, for a given picture, Jennifer both accepted the correct word and rejected the two co-ordinate words. Results are shown in Table 7. Although the category effect appeared less clearly in this task (and it turned out to be not significant: $\chi^2 < 1$), Jennifer performed worse for living (58% correct) than for non-living items (72% correct), with the animal items being performed the worst (44% correct). Qualitatively, there was no clear category effect in the pattern of errors; for both categories the most common error consisted in accepting a close co-ordinate of the target.

Verbal description task: Jennifer was given the names of the 72 experimental items and asked to describe the object they referred to. If she did not describe spontaneously the visual properties of the object, she was explicitly required to do so. The same instructions were given to the control subjects. All the verbal descriptions were tape-recorded and then transcribed to be submitted to four independent judges. Twenty judges participated in that rating. They were divided in five groups of four judges; a given group was asked to rate only one subject's descriptions (Jennifer or one of the four controls). All judges were members of the staff who were not aware of the purpose of this study. A verbal description was scored as correct if at least two out of them recognized the object described. We relaxed the accuracy criterion of being recognized by all the judges because it resulted in very few objects being recognized from the descriptions, including control subjects' ones. This might have been caused by the pragmatic conditions in which subjects had to provide the objects' description. Neither Jennifer nor the control subjects was told that judges would later be asked to read the descriptions and find out which was the object being described. Thus they had to describe an object to somebody (the examiner) who knew what the object was. In such conditions, subject might omit relevant information, in particular, information allowing to discriminate potentially similar candidates, which they should provide to somebody who does not knew what the object was. For instance, a control subject defined a gazelle as 'an animal that looks like a hind with horns'. This description, though not incorrect, did not allow judges to discriminate the animal defined from a more familiar one such as a goat. It must be added that, given the insufficiently constrained conditions in which the subjects had to describe the objects, the data collected cannot be viewed as providing an accurate and complete picture of the knowledge the subjects should have about them. That is the reason why we did not seek to analyse in detail the verbal descriptions say, in terms of the number and types of the various attributes they contained. Table 8 summarizes the scores of Jennifer and the control group. Jennifer's performance was below normal range for living objects (except for vegetables, where her performance was equal to the performance of one of the controls, who performed extremely badly in describing vegetables), but the patient performed exactly as control subjects for non-living objects. A logistic regression analysis revealed that concept familiarity had a significant effect on Jennifer's performance in this task ($\chi^2 = 5.15$, $P < 0.02$), but not word frequency ($\chi^2 = 2.17$, $P > 0.1$). After adjusting for these two factors, the analysis showed a significant category effect ($\chi^2 = 5.82$, $P < 0.02$). The results of the same logistic regression, performed with category membership having four levels (animals/fruit and vegetables/implements/transport) instead of two (living/non-living), indicated that, once concept familiarity and word frequency were adjusted for, the difference between the scores for animals and for fruit and vegetables did not reach a significant level ($\chi^2 = 3.3$, $P > 0.07$). Thus, as it was noted for the naming tasks, there was no evidence here of a more finely-grained dissociation in Jennifer's performance within the living category. The difference between implements and transports did not reach a significant level ($\chi^2 = 2.17$, $P > 0.09$) either. Looking now at the verbal descriptions Jennifer provided for the living objects, and which were not recognized by the judges, one can note that the specific information relevant to discriminate between exemplars of a given category were missing. This was especially the case with animals, for which Jennifer most often provided descriptions of the kind 'it is an animal with four legs and a mouth. It lives in the nature'. For example, asked to define a camel, Jennifer said 'it is an animal that lives in warm countries, it has four legs'. She failed to say that it has humps or that it lives in the desert while, as expected, all the control subjects at least provided one of these relevant properties.

Comments: The results of the semantic tasks clearly indicated that Jennifer's naming difficulties were due to damage located at a semantic processing level. They also suggest that some aspects of semantic knowledge were relatively well spared. Evidence was found, particularly in the outcome of the categorization tasks and the verbal description tasks, that knowledge about category and subcategory membership was well preserved for living as well as for non-living things; size knowledge, which may be viewed as the more general, not very discriminating, physical attribute of an object, appeared spared for the two categories as well. Note that all these aspects of semantic knowledge were equally well retrieved from picture stimuli and word stimuli. Thus, one cannot explain Jennifer's ability to retrieve such semantic properties by appealing only to inferential processes based on visual information available in the picture (Hillis *et al.*, 1990). It appeared that Jennifer could not retrieve, however, those parts of the semantic knowledge that are relevant to discriminate between closely-related concepts, especially when living items are concerned: in the word–picture verification task, Jennifer showed a trend towards a higher error rate for living entities and, in the verbal description task, she provided far less detailed information for living than non-living items. The naming impairment probably originated from the same source: if the semantic representation that is accessed by the patient lacks the relevant properties that discriminate between co-ordinate concepts, no specific word-form could be selected for output.

Assessing visual and functional knowledge for living and non-living entities

Did Jennifer's difficulties in retrieving relevant semantic information about living entities arise from a specific impairment in accessing relevant information about their visual properties? In other words, could the selective impairment touching living entities be accounted for by the hypothesis of damage to a visual semantic subsystem? If visual semantics was selectively disrupted, then Jennifer should have shown a poorer knowledge of the visual attributes than the functional attributes of living entities; furthermore, she should be impaired in retrieving the visual attributes of non-living entities. These predictions were tested through an attribute-verification task.

Method

Statements describing either a visual or a non-visual attribute of an object were prepared so that each of the 72 experimental items appeared in four statements: two describing a visual attribute (one true, one false) and two describing a non-visual attribute (one true, one false); this procedure led to a set of 288 statements. The visual attributes for living as well as non-living items consisted in describing a part of the object (e.g. 'has a mast') or its global appearance (e.g. 'has a very elongated form'). The non-visual attributes referred, for animals, to eating habits (e.g. 'eats the leaves from the trees'), moving habits (e.g. 'moves by jumping'), living environment (e.g. 'lives near rivers'), or human use (e.g. 'is used as transport') and for fruit and vegetables, to taste (e.g. 'has a piquant taste'), cooking (e.g. 'is often used to prepare sauces'), or growing environment (e.g. 'grows on a tree'). Non-visual attributes for implements, referred to their functional use (e.g. 'is used to hit nails') and, for means of transport, stated what is transported (e.g. 'is used for carrying goods'), the context in which it is used (e.g. 'is used during war') or the specific places where it is used (e.g. 'is found in urban areas'). False statements were constructed by assigning a true attribute of an item to another item of the same category. A given attribute, visual or non-visual, appeared equally often in true and false statements. To check the difficulty of the 'visual' and 'non-visual' statements, we asked five well-educated young adults first to verify the 288 statements and then to rate on a 5-point scale how easy it was to respond (1 = very easy; 5 = very difficult). The mean rated difficulty of the 'visual' statements was 1.79 ('true' statements) and 2.11 ('false' statements) for the living items, and 2.01 ('true') and 2.11 ('false') for non-living items. The mean rated difficulty of the 'non-visual' statements was 1.9 ('true') and 2.01 ('false') for the living items, and 1.78 ('true') and 2.09 ('false') for the non-living items. The mean rated difficulty of individual statements was entered into an ANOVA 2 × 2 × 2, with the three factors being item category (living/non-living), attribute type (visual/non-visual), and truth value (true/false). This analysis revealed no significant difference in the difficulty of statements between the two item categories [$F(1,280) < 1$] or between the two attribute types [$F(1,280) < 1$]. No significant item category × attribute type interaction was found either [$F(1,280) < 1$]. The only significant difference was between

Table 9. Number and percentage of Jennifer's and controls' correct responses in the attribute-verification task, according to the attribute-type

	Jennifer		Controls		
	n	(%)	Mean	(%)	Range
Visual attributes					
Animals	6/18	(33.3%)	13.25/18	(73.6%)	8–16
Fruit and vegetables	9/18	(50%)	14/18	(77.8%)	13–15
Living entities (total)	15/36	(41.7%)	27.25/36	(75.7%)	23–30
Implements	11/18	(61.1%)	12/18	(66.7%)	10–15
Transport	16/18	(88.9%)	15.25/18	(84.7%)	15–16
Non-living entities (total)	27/36	(75%)	27.25/36	(75.7%)	25–31
Functional attributes					
Animals	7/18	(38.9%)	14/18	(77.8%)	13–16
Fruit and vegetables	11/18	(61.1%)	12.75/18	(70.8%)	10–18
Living entities (total)	18/36	(50%)	26.75/36	(74.3%)	23–34
Implements	15/18	(83.3%)	14.5/18	(80.6%)	13–16
Transport	15/18	(83.3%)	15/18	(83.3%)	14–17
Non-living entities (total)	30/36	(83.3%)	29.5/36	(81.9%)	27–31

'true' and 'false' statements [$F(1,280) = 6.74$; $P < 0.01$), the latter being more difficult; however, this factor did not interact with the two others [all $F(1,280) < 1$].

The 288 statements were divided into four lists: two lists of 72 'visual' statements and two lists of 72 'non-visual' statements. Within a list, an item appeared only in one statement (either the true or the false one). Jennifer was presented the statements in two sessions with a period of two weeks in between. Within each session, she was presented a visual and a non-visual list. She was asked to tell if the statement was true or not.

Results

Jennifer's responses to the statements describing visual attributes and the statements describing non-visual attributes were scored separately. An item was scored as correct when both the true statement was accepted and the false one rejected. Table 9 summarizes Jennifer's and the control group's results according to the attribute, visual or non-visual, that was to be verified. (Note that, for visual as well as for non-visual statements, Jennifer's errors consisted both in rejecting true statements and accepting false ones, with a very similar rate.) The results revealed two interesting points: (1) Jennifer's performance was below normal range for both visual and non-visual attributes when living entities were probed, with both types of attributes appearing equally impaired; (2) she was perfectly within normal range for both visual and non-visual attributes when non-living entities were concerned, with both types of attributes appearing equally spared. Thus, a clear semantic-category effect appeared while there was no evidence for an attribute or an attribute-by-category interaction effect. The results of the logistic regression analysis revealed that word frequency and concept familiarity had no significant effect on performance in this task (for visual attributes, word frequency: $\chi^2 < 1$ and familiarity: $\chi^2 < 1$; for non-visual attributes, word frequency: $\chi^2 = 2.75$, $P > 0.09$ and familiarity: $\chi^2 = 2.04$, $P > 0.1$). After adjusting for the effects of these two factors, the semantic-category effect turned out to be significant (for visual attributes: $\chi^2 = 6.87$, $P < 0.01$; for non-visual attributes: $\chi^2 = 6.34$, $P < 0.01$). We performed the same logistic regression, but with category membership having four levels (animals/fruit and vegetables/implements/transport) instead of two (living/non-living). The results showed that, once concept familiarity and word frequency were adjusted for, the scores for animals and for fruit and vegetables did not differ significantly in any of the attribute-verification tasks (for visual and non-visual attributes: $\chi^2 < 1$). Again, no evidence could be found here in favour of a further dissociation within the living category. Within the non-living category, the scores for implements and transport did not differ significantly when non-visual attributes were probed. However, when probed with visual attributes, performance with transport was significantly better than with implements ($\chi^2 = 3.86$, $P = 0.05$). Still, the scores of the control subjects showed the same pattern. Such a pattern might have the same underlying cause as the one tentatively proposed above to account for the difference between implements and transport in Jennifer's naming performance from a verbal description. Namely, the statements describing visual attributes of implements might contain less familiar verbal labels than those describing transport.

Discussion

The outcome of the attribute-verification task provides clear evidence that a category-specific naming impairment for living entities is not necessarily associated with disproportionate difficulties in processing the visual attributes of concepts: (1) Jennifer appeared as much impaired in retrieving the visual attributes of the living entities than in retrieving their non-visual attributes; (2) she appeared not at all impaired in retrieving the visual attributes of the non-living entities. At the same time, Jennifer did encounter disproportionate difficulties in processing living concepts in comparison with non-living concepts, whether their visual or non-visual parts were concerned. Thus, the semantic-category effect found in the naming and the verbal description tasks was also found when the patient only had to verify the semantic attributes of entities. Such a pattern strongly suggests that Jennifer suffers from a semantic impairment that selectively affects a category, not a kind of attribute.

General discussion

In the present paper, we reported a further case of a patient showing a category-specific naming impairment affecting living entities (animals, fruit and vegetables). We showed that the living/non-living dissociation present in the patient's naming performance was not an artefact of uncontrolled stimulus factors such as picture's visual complexity, concept's familiarity, and word frequency. We also showed that the living/non-living dissociation observed in naming was consistent across time, input modalities (i.e. whether pictures or verbal descriptions were presented as stimuli) and output modalities (i.e. whether a spoken or a written word was required as response). Furthermore, a very high item-consistency was found across time and input/output modalities. All these observations pointed out the semantic processing level as the likely locus of damage causing naming difficulties and, hence, as the processing level that is sensitive to the living/non-living distinction.

This hypothesis found some support from the outcome of pre-semantic and semantic tasks that did not require the production of a target word. The patient did not appear to be impaired in retrieving the stored structural description of the objects depicted in pictures or the stored phonological word-form of their auditorily presented name. In contrast, she appeared clearly impaired in retrieving complete semantic information about living entities, either from pictures or spoken words. Thus, the patient showed a higher error rate for living, especially animals, than for non-living objects when she had to verify whether a word corresponded to a given picture, and provided less detailed information for living than for non-living things when asked to describe verbally the object a spoken word refers to.

We then asked whether the category-specific deficit for living entities found in our patient could be accounted for by the hypothesis of damage touching selectively the visual semantic system by leaving intact the functional semantic system (Warrington and Shallice, 1984; Farah and McClelland, 1991). This sensory–functional account of the disproportionate processing difficulties for living entities predicts, first, that the patient should be more impaired in retrieving visual than functional semantic properties of living entities, second, that her abilities to retrieve visual semantic properties of non-living entities should not be entirely spared. None of these predictions was confirmed by the results of the attribute-verification task: the patient's abilities in retrieving visual and functional attributes of living things appeared equally impaired, her abilities in retrieving visual attributes of non-living things appeared quite spared. Hence, the hypothesis of damage touching selectively the visual component of the objects' semantic representation could not account for the living/non-living dissociation found in our patient.

While the results of the present case study allow us to reject a sensory–functional account for the living-things impairment found in our patient, they do not allow us to reject the model of semantic organization underlying this account, namely, the hypothesis that semantic representations are organized according to the type of knowledge, or type of attribute, being represented. The results of the present case study are indeed silent about whether the visual and the non-visual components of an object's semantic representation are stored in distinct attribute-specific semantic systems or within a single, attribute-independent, semantic system. They seem to require, however, the hypothesis of multiple attribute-specific systems to be modified by an additional assumption, so that it could account for the appearance of a category effect in the absence of an attribute effect. Such a requirement might be achieved by assuming the semantic system being organized both by attribute and category. Both organizing principles, which are not necessarily conflicting, could be given theoretical justification. Thus, the semantic representation system might have inherited (one of) its organizing principle(s) from the existence of peripheral modality-specific processing channels, sensory (visual, olfactory, auditory . . .) and motor channels, to which it is tied. It might just as well have inherited (one of) its organizing principle(s) from the existence of specialized processes for rapid and accurate classification of objects as animals, plant life, or neither of these two categories of objects, a specialization that would result from evolutionary adaptations (Caramazza and Shelton, 1998).

On these theoretical bases, one can assume a semantic organization in which the visual/functional distinction would be orthogonal to the living/non-living one (Powell and Davidoff, 1995; Gainotti and Silveri, 1996). Accordingly, each of the four functionally distinct semantic systems resulting from these two × two levels of organization, the living/visual, the non-living/visual, the living/functional, and the non-living/functional systems, could be selectively disrupted following brain damage. Hence such a model would be able to account for the various patterns of category-specific deficits for living things reported, whether they were associated or not with disproportionate difficulties in visual semantic processing. According to this model, the cases of category-specific impairment for living things that were shown to be selectively impaired in retrieving visual semantics for both categories (Powell and Davidoff, 1995; Gainotti and Silveri, 1996) would result from selective damage to the living/visual and the non-living/visual semantic systems. The present case (as well as similar ones recently reported by Laiacona *et al.*, 1993, 1997;

Caramazza and Shelton, 1998), which is not disproportionately impaired in visual semantic processing, would result from selective damage to the living/visual and the living/non-visual systems.

However, the question could be raised whether empirical evidence to date is compelling enough to require such an uneconomical account of category-specific deficits. In other words, whether the more parsimonious hypothesis of a semantic system being organized along the living/non-living dimension alone could not be able to explain the various patterns of category-specific deficits reported, including those that were interpreted as attribute-specific deficits. We would like at least to underline here that evidence that was put forward in favour of the attribute-specificity interpretation is, in fact, open to an alternative interpretation.

The ambiguity lies in the assumption that is made about the cognitive processing demands involved in the tasks that were commonly used to document the attribute-specific deficit. In the critical studies, (Basso *et al.*, 1988; Hart and Gordon, 1992; De Renzi and Lucchelli, 1994; Powell and Davidoff, 1995; Gainotti and Silveri, 1996), a selective deficit in processing visual semantics has been inferred from the patients' impaired performance in verifying or describing visual attributes of objects from spoken words, or in providing the name of an object from a verbal description of its visual attributes, while normal performance was noted in these tasks when functional attributes were probed. It is, however, not explicitly stated how performance showed in these 'visual semantic' tasks is assumed to be related to the processing capacities that are sought to be assessed. Stemming from the implications that were drawn from the outcome of these tasks, one can suppose that it was implicitly assumed that these tasks only required a kind of direct 'look-up' into the object's visual semantic representation. This assumption might be wrong. In order to verify, for example, whether a tractor 'has the back wheels bigger than the front wheels', or in order to provide a verbal description of the physical properties of a tractor, retrieving the set of visual and functional attributes that represent the meaning of the word 'tractor' might not suffice. We will make the proposal that both these tasks require further explicit mental evocation of the physical properties of the tractor, namely, an evocation taking the form of a mental image. We propose, in other words, that these tasks at least call for the following cognitive operations: (1) retrieving the visual semantics of the object from its spoken name; (2) accessing, on this basis, its stored structural description; and (3) using this structural description to construct a visual mental image of the object. Similarly, in order to name the object described as 'has the back wheels bigger than the front wheels', subjects might first have to access and integrate into a mental image the stored structural features corresponding to the name of each of the physical properties provided in the verbal description; then, they could retrieve the appropriate visual and functional semantic representations needed for selecting the object's name (see Sartori and Job, 1988, for a similar proposal). Hence, impaired performance in such 'visual semantic' tasks could not only result from a deficit in retrieving objects' visual semantics, but also from a deficit in retrieving stored structural descriptions or in constructing mental images. It should be noted that impaired structural processing or impaired imagery processes could also give rise to a category effect in performance. That would not necessarily imply that living and non-living objects are processed by functionally distinct structural or imagery systems. Damage to such processing levels may impair performance of living things more than non-living things simply because living stimuli might require access to more detailed levels of structural representation (Riddoch *et al.*, 1988; Sartori *et al.*, 1993; Forde *et al.*, 1997) or the construction of more fine-grained visual images.

Information about the integrity of visual imagery and/or structural processes is not provided for a number of cases of category-specific deficits that have been reported as having impaired performance in 'visual semantic' tasks (Basso *et al.*, 1988; Hart and Gordon, 1992; Gainotti and Silveri, 1996). Such information is provided only for two cases presenting with this pattern, Felicia, reported by De Renzi and Lucchelli (1994) and NB described by Powell and Davidoff (1992, 1995). At the same time, Felicia showed impaired performance in an object decision task, namely a task that is commonly assumed to assess the ability to retrieve the stored structural description of the objects; furthermore, in that task, Felicia was more impaired for living than for non-living things. As for NB, his ability to form a complete mental image of objects was impaired; when asked to visualize a specific object, the patient could form a mental image of only some parts or formed a distorted image of it. Hence, if the assumption we made about the cognitive processing demands involved in 'visual semantic' tasks is correct, one cannot rule out an account of Felicia's and NB's difficulties in these tasks in terms of a structural processing or visual imagery deficit, instead of a visual semantic deficit. Thus, cases who are impaired in 'visual semantic' tasks but, at the same time, are impaired in visual imagery or structural processing, are ambiguous as to the damaged processing component that is responsible for the impairment in the 'visual semantic' tasks. Accordingly, they cannot provide compelling evidence that visual semantics may be selectively damaged. If cases of category-specific deficits were documented, who would show disproportionate difficulty in processing the visual attributes of the objects in the face of spared structural knowledge, this would constitute more compelling evidence in favour of the existence of attribute-specific deficits. As far as we know, no such pattern has been reported to date. Until it has, there will be no need to assume a by-attribute, in addition to a by-category organization of semantic representations in order to account for the category-specific deficits.

In conclusion, we have described a patient whose pattern of specific naming impairment for living entities cannot be accounted for by the hypothesis of selective damage to visual semantics. What appeared to be selectively impaired in this patient was not visual semantics but rather semantics of living entities. Such a pattern thus strongly points to the need of considering, more seriously than it has been so far, the assumption that the living/non-living dimension represents a fundamental organizing principle of semantic representations. The results of this case study are silent, however, on the complex issue of how such a principle is realized: in an 'explicit' way, the semantic representations of living and non-living entities being processed by two functionally distinct semantic systems (as proposed by Caramazza and Shelton, 1998), or in an 'implicit' way, the organization along the living/non-living dimension being rather a property emerging from patterns of feature correlations (as proposed by McRae *et al.*, 1997; see also Riddoch *et al.*, 1988 and Hillis *et al.*, 1995 for related proposals) or even context correlations (Ritter, 1990) between exemplars of a given category. Resolving such an issue will undoubtedly be a challenge to researchers in semantic memory disorders. We hope at least to have provided some arguments to make this challenge appear as a relevant one.

Acknowledgements

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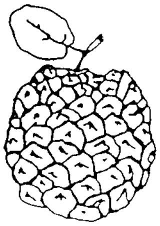
Appendix A

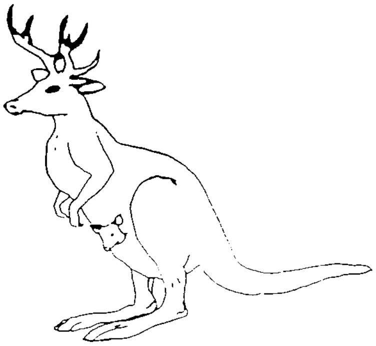
Appendix A. List of items used in the experimental study

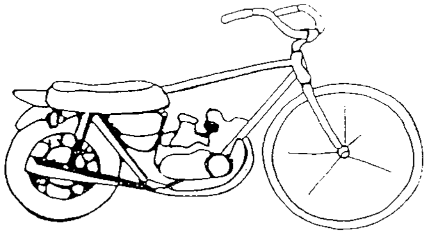
Living entities	
Animals	*Fruit and vegetables*
âne (donkey)	ananas (pineapple)
biche (hind)	artichaut (artichoke)
cerf (deer)	aubergine (eggplant)
chameau (camel)	cacahuète (peanut)
cheval (horse)	carotte (carrot)
écureuil (squirrel)	cerise (cherry)
éléphant (elephant)	champignon (mushroom)
gazelle (gazelle)	courgette (courgette)
girafe (giraffe)	fraise (strawberry)
hippopotame (hippopotamus)	kiwi (kiwi)
kangourou (kangaroo)	pastèque (water melon)
lama (llama)	petits pois (garden peas)
lion (lion)	piment (pimento)
phoque (seal)	poireau (leek)
raton-laveur (raccoon)	pomme (apple)
renard (fox)	pomme de terre (potato)
singe (monkey)	raisin (grape)
zèbre (zebra)	tomate (tomato)
Non-living entities	
Implements	*Means of transport*
agrafeuse (stapler)	ambulance (ambulance)
ciseaux (scissors)	avion (aeroplane)
clé à molette (adjustable spanner)	barque (boat)
compas (compass)	bus (bus)
crayon (pencil)	camion (truck)
hache (axe)	fusée (rocket)
machine à écrire (typewriter)	hélicoptère (helicopter)
marteau (hammer)	mobylette (light motor cycle)
pelle (shovel)	montgolfière (balloon)
pince (pliers)	moto (motorbike)
pioche (pickaxe)	paquebot (liner)
rateau (rake)	sous-marin (submarine)
scie (saw)	tank (tank)
stylo (pen)	train (train)
téléphone (telephone)	tram (tramway)
tournevis (screwdriver)	vélo (bike)
trombone (paper clip)	voilier (sailing boat)
tronçonneuse (chain saw)	voiture (car)

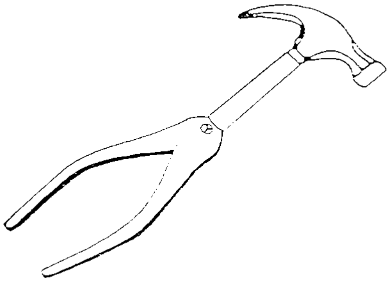
Appendix B

Examples of unreal objects used in the object decision task









Impaired knowledge of visual and non-visual attributes in a patient with a semantic impairment for living entities: a case of a true category-specific deficit

D. Samson, A. Pillon and **V. De Wilde**

Abstract

We report a single case study of a 22-year-old, brain-damaged patient, Jennifer, who showed a semantic deficit affecting living entities (animals and fruit and vegetables) to a greater extent than non-living ones (implements and means of transport). We first show that this category effect was reliable both across time and naming conditions and that it was not an artefact of uncontrolled stimulus factors. We then show that Jennifer had no impairment at the visual or structural processing level and that her deficit was probably located at a semantic processing level. Specific semantic deficits for living entities have usually been explained by damage to the visual semantic system. However, when Jennifer's access to visual and non-visual semantics was assessed through an attribute-verification task, no evidence of an attribute-specific impairment was found: Jennifer was equally impaired in retrieving visual and non-visual attributes of living entities and she was not at all impaired in retrieving visual attributes of non-living entities. Thus, the hypothesis of damage to visual semantics cannot account for the pattern of living things impairment found in this patient. Rather, this pattern seems to require the assumption that the semantic system is organized according to the living/non-living dimension.

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O120

Primary diagnosis of interest

Selective semantic impairment for living things

Author's designation of the case

Jennifer

Key theoretical issue

- Selective semantic impairment for living things without selective 'visual semantic' deficit

Key words: category-specific deficit; semantic impairment; living/non-living dissociation; visual and functional knowledge

Scan, EEG and related measures

CT scan

Standardized assessment

BORB, Doors Test, Buschke

Other assessment

Oral and written picture naming, oral naming to description, object decision, lexical decision, categorization, size judgement, word–picture verification, description, attribute verification

Lesion location

- Left temporal lobe

Lesion type

Trauma

Language

English