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WHAT ARE THE FACTS OF SEMANTIC CATEGORY-SPECIFIC DEFICITS? A CRITICAL REVIEW OF THE CLINICAL EVIDENCE

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In this study we provide a critical review of the clinical evidence available to date in the field of semantic category-specific deficits. The motivation for undertaking this review is that not all the data reported in the literature are useful for adjudicating among extant theories. This project is an attempt to answer two basic questions: (1) what are the categories of category-specific deficits, and (2) is there an interaction between impairment for a type of knowledge (e.g., visual, functional, etc.) and impairment for a given category of objects (e.g., biological, artefacts, etc.). Of the 79 case studies in which the reported data are sufficiently informative with respect to the aims of our study, 61 presented a disproportionate impairment for biological categories and 18 presented a disproportionate impairment for artefacts. Less than half of the reported cases provide statistically and theoretically interpretable data. Each case is commented upon individually. The facts that emerge from our critical review are that (1) the categories of category-specific semantic deficits are animate objects, inanimate biological objects, and artefacts (the domain of biological objects fractionates into two independent semantic categories: animals, and fruit/vegetables); (2) the types of category-specific deficits are not associated with specific types of conceptual knowledge deficits. Other conclusions that emerge from our review are that the evidence in favour of the existence of cases of reliable category-specific agnosia or anomia is not very strong, and that the visual structural description system functions relatively autonomously from conceptual knowledge about object form.

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INTRODUCTION

A central issue in the cognitive brain sciences is the organisation of conceptual knowledge in the human brain. The neuropsychological phenomenon of category-specific semantic deficits, in which the ability to identify specific categories of objects can be selectively impaired while performance with other categories remains relatively intact, provides an empirical basis for theories directed at the organisation of conceptual knowledge in the brain. Such theories can be divided into two groups, according to their underlying basic principle: the *correlated structure principle*, which assumes that the organisation of conceptual knowledge in the brain is a reflection of the statistical co-occurrence of the properties of objects, and the *neural structure principle*, which assumes that the organisation of conceptual knowledge is governed by representational constraints imposed by the brain itself.

The central assumption shared by theories based on the *correlated structure principle* is that any structure in the organisation of conceptual knowledge in the brain reflects the way in which properties of objects are statistically related to one another in the world. One proposal based on the correlated structure principle is the Organised Unitary Content Hypothesis (OUCH) (Caramazza, Hillis, Rapp, & Romani, 1990). In this account, conceptual space is lumpy, in that objects that share many properties tend to be represented together. For instance, the semantic representations of things that are made of a certain kind of stuff, have similar shapes, or are capable of self-generated movement might cluster together. If it is assumed that brain damage can selectively affect lumpy areas of conceptual space, either because these conceptual clusters are neurally contiguous and thus susceptible to selective damage, or because damage to a given property will propagate to highly correlated properties, then it is possible for specific categories of objects to be damaged (relatively) independently of one another. Other OUCH type models contrast the "distinctiveness" of object properties with the "correlation" of object properties (Garrard, Lambon Ralph, Hodges, & Patterson, 2001; Tyler & Moss, 1997). For instance, in one account, the highly correlated properties of items from biological categories would reinforce each other, thus making the category of living things less susceptible to impairment under conditions of moderate brain damage (Devlin, Gonnerman, Andersen, & Seidenberg, 1998). Contrastively, other authors have argued that the representations of artefacts should be less susceptible to moderate brain damage due to the high correlation between the distinctive form of an artefact and its function (Moss, Tyler, Durrant-Peatfield, & Bunn, 1998).

The crucial aspect to all OUCH-type theories is that the organising principle of conceptual knowledge in the brain is not semantic (e.g., animate vs. inanimate), but the degree to which properties of objects tend to co-occur in the world. Because of this, theories of category-specific deficits based on the correlated structure principle make two predictions: (1) any category that is sufficiently compact in conceptual space (either because its members map onto conceptual clusters or because of links among their highly correlated properties) is a candidate for selective damage/sparing; (2) selective damage to a semantic category will equally affect all types of knowledge of that category.

Two types of theories based on the *neural structure principle* have been proposed. Common to these theories is the assumption that the organisation of conceptual knowledge is determined by representational constraints internal to the brain. However, the first class of theories and, until recently, the received view, assumes that category-specific impairments arise from a noncategorically organised semantic system. Instead, this class of theories holds that conceptual knowledge is distributed across functionally and neuroanatomically distinct modality-specific semantic subsystems, each dedicated to storing and processing a specific type of information: e.g., visual, motor, auditory, etc. It is also assumed by this class of theories that the ability to identify different categories of objects depends differentially on the integrity of processes internal to distinct modality-specific subsystems. In the original account (Farah & McClelland, 1991; Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984), the ability to identify living things depends differentially upon processes internal to the visual semantic subsystem, while the ability to identify nonliving things depends differentially upon processes internal to the functional/associative semantic subsystem: the sensory/functional theory (SFT). Throughout this paper we will use the terms "functional/associative" and "perceptual" to refer to different aspects of conceptual knowledge because these terms are widely employed in the literature; however, it should be made clear that their contrast is not based on a corroborated theory of how knowledge is acquired or represented. In particular, it is not clear if the contrast between functional/associative and perceptual semantic information (and, according to some authors, between correspondingly distinct semantic subsystems) depends on how (i.e., along which channel) the information is acquired, or on the format according to which the information is encoded or stored (for discussion, see Shelton & Caramazza, 2001). In the practice of most authors, the operational meaning of "functional/ associative" knowledge has a rather wide scope, encompassing many different aspects of conceptual knowledge, which may or may not coincide for items from different categories: e.g., what an object is used for, how it is used, where it is usually found, whether it moves and how it moves, etc. The term "perceptual" knowledge is sometimes used in reference to information about the visual appearance (i.e., the shape and texture of an object), but it is sometimes also used to refer to information that can be directly perceived in the presence of the object through perceptual channels different from the visual modality.

In recent years, several variants of the SFT have emerged, each modifying the details of how different categories of objects depend differentially on different modality-specific systems. For instance, Humphreys and Forde (2001; see also Humphreys, Riddoch, & Quinlan, 1988) assume that living things are more visually similar, with the result that there will be more perceptual crowding among the structural descriptions of living things compared to those of nonliving things. Thus, damage to the (visual) structural description system will tend to affect the category living things disproportionately compared to the category nonliving things. Also recently, Borgo and Shallice (2001) have assumed that the identification of living things, as well as several other "sensory quality categories" such as nonedible materials, liquids, and edible substances, depends differentially on colour and texture information. On this account, these "sensory quality categories" (i.e., living things, nonedible materials, liquids, edible substances) should never dissociate from one another under conditions of brain damage. Finally, Martin, Ungerleider, and Haxby (2000) have proposed a third variant of the SFT: the sensory/motor theory (SMT). The SMT makes the same assumption regarding living things as the original SFT, but assumes that for manipulable artefacts, the ability to identify such objects depends upon intact knowledge of how to use them.

The common assumption shared by modality-specific theories is that category-specific impairments are not truly categorical impairments, but are rather impairments to a modality of knowledge (e.g., visual, functional, etc.) upon which the ability to identify exemplars from certain domains of objects differentially depends. Thus, *all modality-specific theories are committed to the prediction that there will be an association between an impairment to a type of knowledge (e.g., visual, functional, etc.) and an impairment to a category of objects (e.g., biological objects, artefacts, etc.)*. Specifically, three predictions are made: (1) An impairment to the visual modality implies an impairment for the category of biological objects, while an impairment to the functional modality implies an impairment for the category of artefacts; (2) an impairment for biological objects implies a deficit for visual knowledge, while an impairment for artefacts implies a deficit for functional/ associative knowledge; and (3) the grain of category-specific deficits must necessarily be coarse, reflecting the relative importance of different modalities of conceptual knowledge for identifying different semantic categories. The latter prediction follows from the assumption that if a type of modality-specific knowledge is damaged it will necessarily result in impairment of *all* the categories for which this type of knowledge is central. For example, damage to visual conceptual knowledge should result in impairment for at least the categories animals, musical instruments, and fruits and vegetables. Stated differently, we should not observe category-specific deficits restricted to the category of animals or the category of fruits and vegetables.

The second class of theories based on the neural structure principle is the domain-specific account (Caramazza & Shelton, 1998; see also Santos & Caramazza, 2002; Shelton & Caramazza, 2001). In this account, the broadest dimension for the organisation of conceptual knowledge in the brain is determined by the role that objects have played in our evolutionary history. Specifically, it is assumed that selection pressures have resulted in *domain-specific neural circuits* dedicated to solving, quickly and efficiently, computationally complex survival problems (for example, avoiding predators and finding food). Obvious candidate domains are animals, conspecifics, and plant life (and possibly tools; see Hauser, 1997, for discussion of this possibility). The domain-specific account makes two predictions: (1) brain damage can result in category-specific semantic deficits only for evolutionarily defined domains; (2) selective damage to a semantic category will equally affect all types of knowledge about that category.

The literature on category-specific deficits is currently quite large (see recent reviews in Caramazza, 1998; Forde & Humphreys, 1999; Gainotti, 2000; Humphreys & Forde, 2001). About three quarters of reported cases present a greater impairment for biological categories, and about one quarter present the opposite pattern. For most of the reported cases, category-specific naming deficits have been interpreted as reflecting an impairment to semantic knowledge; however, some cases have been interpreted as reflecting damage to pre-semantic, object recognition systems (e.g., damage to the structural description system: agnosic patients), while some cases have been interpreted as reflecting damage to post-semantic, that is, lexical representations. The term "agnosia" classically refers to those deficits of object identification restricted to a given input channel, in the absence of elementary sensory impairments affecting the same channel. With respect to visual agnosia, the historical distinction between apperceptive agnosia (referring to damage to very preliminary stages of perception) and associative agnosia (referring to the missed "association" between what is actually perceived and the stored "generalised' shape of an object) is certainly a simplification. It is commonly assumed that information about the "generalized" or "canonical" shape of a given object is stored separately from semantic information, and is represented in a "structural description system" that only contains information about the visual properties but not other types of information about the stimulus. Furthermore, the semantic system itself certainly contains information about the visual/perceptual properties of objects. However, we neither have a corroborated theory about the relationship between the representations stored in the structural description system and those stored in the semantic system(s), nor do we know exactly how these representations dynamically interact while a subject performs a cognitive task.

Not all of the data reported in the category-specific literature is useful for adjudicating among the extant theories of category-specific deficits, for several reasons. First, many of the early reports did not control for various "nuisance" variables known to affect performance. For example, early studies did not always control for stimulus familiarity or visual complexity. However, it is now clear that the phenomenon of category-specific deficit cannot be dismissed as the result of uncontrolled stimulus factors, as many cases have since been reported in which the relevant concomitant variables have been controlled. Second, many authors did not collect the kind of data required to distinguish between the various theories that have been proposed to explain category-specific deficits. And third, the reported results are at times not sufficiently clear to permit unambiguous interpretation. Thus, it is crucial to critically review and evaluate the literature on category-specific deficits in order to separate those cases that are useful in distinguishing among theories from those that are not. As such a project, this article is driven by an attempt to answer two questions that will allow for an evaluation of the alternative theoretical accounts that have been advanced to account for category-specific semantic deficits. The core issues addressed in this review are as follows. First: What are the categories of category-specific deficits? This is an important theoretical question, as different theories make different predictions as to the type and distribution of category effects that may be observed. Second: Is there an interaction between impairment for a type of knowledge (e.g., visual, functional, etc.) and impairment for a given category (e.g., biological, artefacts, etc.)? The status of the modality-specific theories turns on the answer to this question, as all such theories require that there be an association between a type of knowledge impairment and a specific pattern of category-specific deficit. The predictions made by the principal theories are summarised in Table 1.

We wish to emphasise that the scope of the analyses reported here is limited to consideration of the issues discussed above. It is not our intention to evaluate individual, specific theories of the causes of semantic category-specific deficits or specific theories of the organisation of conceptual knowledge. Instead, our objective is to establish as clearly as possible the *facts* that emerge from neuropsychological investigations of semantic category-specific deficits, insofar as they concern (1) the grain of the categories affected and (2) the type (modality) of conceptual knowledge that is affected in the various types of category-specific deficits.

The paper is organised as follows. We begin with a description of the database on which our critical review is based. This is followed by the results of several analyses, the details of which are reported in appendices so as not to clutter the presentation of the results. First, we report the analysis of the attested types of category-specific deficits, focusing on the patterns of relationship between category-specific deficits and impairments of types of knowledge about objects. Specifically, we consider whether patients with category-specific deficits for biological categories are also disproportionately impaired for knowledge of the visual properties of objects. That is, we attempt to answer the question: What is the nature of the deficit in patients with category-specific deficits? Second, we report an analysis of the grain of the observed deficits. Here we consider both the issue of whether the category of biological concepts fractionates into finer-grained category-specific deficits as well as whether there are specific patterns of associations as predicted by the SFT. That is, we answer the question: What are the categories of category-specific deficits? We conclude with a brief assessment of what we consider to be the core facts that emerge from our analysis of the literature (at least with respect to the grain of category-specific deficits and the relationship between modality of knowledge and category effects).

ANALYSIS OF THE DATABASE

The database for a critical review

Beginning with the first informative study in the literature (Warrington & Shallice, 1984), we have evaluated all the published papers on semantic category-specific deficits through the year 2001. This survey focuses on the dissociation (in either direc-

Table 1. *Schematic representation of the basic predictions entailed by the main types of explanations of category-specific deficits*

	Categories selectively or disproportionately impaired	*Type of knowledge defective in the (most) impaired categories*	*Type of knowledge defective in the (relatively) spared categories*
	Theories based on the correlated structure principle		
OUCH-type	Any category sufficiently compact in conceptual space	All types of knowledge	No specific impairment
	Theories based on the neural structure principle		
SFT-types	All categories for which the crucial modality-specific subsystem is damaged (e.g., biological categories)	Semantic information crucial for the impaired category (e.g., visual)	Semantic information crucial for the impaired category (e.g., visual)
D-S account	Only evolutionarily salient categories (e.g., animals, fruit and vegetables, conspecifics (tools?))	All types of knowledge	No specific impairment

tion) between biological and artifact categories. We found 79 case studies in which the reported data are sufficiently informative with respect to the aims of our study. We did not consider those cases in which the data are not clearly reported or were not submitted to a statistical analysis, even if such data could be potentially relevant (e.g., Damasio, 1990, cases AN and PSD; Goldenberg, 1992; Laurent et al., 1990, Case 9). We also excluded cases of developmental category-specific deficit (e.g., Temple, 1986). Appendix A lists all the cases included in this database: Section 1 lists single cases presenting a disproportionate impairment for living categories (*n* = 61); Section 2 lists cases presenting a disproportionate impairment for nonliving categories (*n* = 18).

For each case listed in Appendix A1 and A2, demographic data, aetiology, and lesion site are reported. Moreover, we report all available data that bears on the disproportionately impaired categories, emphasising which level of representation was determined by the authors to be the locus of the deficit, and indicating if other categories were affected outside the classical realms of living and nonliving.

From group studies or multiple single case studies 76 patients were found who presented with a disproportionate category-specific impairment: 42 were more impaired for biological categories, and 34 for artefacts. Appendix B summarises the relevant information reported in the reference papers. These studies, however, were too limited, or only summary accounts were presented; therefore, these patients were not considered for further evaluation.

What is the nature of the deficit in putative cases of semantic category-specific deficit?

In this section we address several issues. We begin by identifying those patients for whom we have sufficient data to address the core question: "What is the nature of the deficit in patients with semantic category-specific deficits?" These patients are then classified according to whether they have a conceptual level deficit for a particular semantic category, and whether the deficit is uniform across perceptual and functional knowledge about category members. This classification will then serve as the basis for drawing empirical generalisations about the nature of category-specific deficits and for a general evaluation of the major theories of the organisation of conceptual knowledge in the brain.

Authors' classification of cases of category-specific deficit

Table 2 reports the authors' claims regarding the level and type of deficit for the cases listed in Appendix A. These are all the cases for which a first-pass analysis suggests that the reported data may be sufficient to permit conclusions regarding three specific questions: (1) the type of semantic knowledge (perceptual or functional) that is impaired in each patient; (2) whether this impairment applies to all categories or only those for which the patient's performance is disproportionately impaired; and (3) whether the (visual) structural description system is impaired, and if so, whether this pre-semantic impairment is itself category-specific. The table is partitioned into sections, reporting separately those cases presenting a disproportionate impairment for biological categories (Table 2a), and those presenting the opposite dissociation (Table 2b). In the table are also reported patients with category dissociations interpreted by the authors as reflecting purely agnosic or lexical deficits.

Classification of cases of category-specific deficits following reanalysis of the reported results

The cases reported in Table 2 were submitted to a critical analysis. Bibliographic and other information about the cases are listed in Appendix A. The results of the critical review are reported separately for each case in Appendix E. Comments on the case reports are listed in alphabetical order according to the patients' initials; patients are separated into those presenting a disproportionate impairment for natural categories, and those presenting the opposite dissociation. In Appendix E we comment on whether or not the claims made by the respective authors are empirically well founded.

Table 2(a). *Author's classification of the nature of the cognitive impairment: Cases with category-specific impairment involving the biological categories*

Level of impaired knowledge	*Structural description system*	*Cases*
Semantic deficit	Spared.	No cases.
Perceptual attributes worse than	Defective for biological categories.	SRB[a].
functional/associative attributes for all categories.	Defective overall.	DM94, EC.
Semantic deficit	Spared.	KR.
Perceptual attributes worse than functional/ associative attributes only for biological categories.	Defective for biological categories.	FELICIA, GIULIETTA, HELGA, LH, MICHELANGELO.
	Not tested or inconclusive.	LA.
Semantic deficit	Spared.	EA (2nd 3rd exam), FM, JENNIFER, LF, SB.
Perceptual and functional/associative attributes evenly impaired for biological categories.	Defective for biological categories.	CA, DB[a], EA (1st exam), EMMA[a], EW, GR, JBR[a], MF.
	Defective overall.	MU.
	Not tested or inconclusive.	RC.
Semantic deficit	Spared.	BD, SE (contradictory data).
Data insufficient for determining which	Defective for biological categories.	DM97[a].
type of knowledge is more impaired.	Not tested or inconclusive.	C(CW97), FA, FB, FI, GP97, ING, JH, JMC, JV, KB, KG, MB, MC, NV, PR, PS, RM, SBY, TOB, TS, VG.
Deficit level not determined	Defective for biological categories.	IL.
	Not tested.	GC, NR.
Deficit classified as agnosic	Spared.	MR. W.
	Spared on object reality decision, but impaired on heads test.	JB.
	Defective for animals.	ELM.
	Defective.	NA[a].
	Defective with outline drawings, spared with silhouette.	HJA.
	Not tested.	FS, MS.
Deficit classified as lexical	Borderline.	DANTE.
	Not tested.	MD, TU, 5 cases by H. Damasio et al., 1996.

Deficits are classified in terms of the type of category and the type of knowledge (perceptual vs. functional/associative) that are hypothesized to be impaired. The status of patients' structural description system is also reported.
[a]Artefacts not reliably tested.

We also provide our interpretation of the locus of impairment with respect to three levels of representation: semantic, lexical, or pre-semantic (agnosia). The criteria for including cases of dissociation between biological categories and artefacts, and between sensory and functional properties, were (1) a detailed quantitative report of differences in performance, (2) a comparison with control data obtained using the same materials, and (3) a statistical significance assessment, unless the pattern of data was self-evident. In general, the reported cases presented a disproportionate impairment of one category or of one type of knowledge. Less frequently, the impairment was restricted to a given category, while performance on other categories was within normal limits: remarks on this latter type of case profile can be found for the relevant cases in Appendix E. For those cases in which the reported data analyses did not permit a definitive classification, we have attempted to supplement the analyses provided by the authors with new analyses based on the available published data. The type of analysis we have performed is based on the study of 2 × 2 × 2 contin-

Table 2(b). *Author's classification of the nature of the cognitive impairment : Cases with category-specific impairment involving artefacts*

Level of impaired knowledge	*Structural description system*	*Cases*
Semantic deficit Perceptual attributes worse than functional/ associative attributes for all categories.	Spared. Defective.	IW. SM.
Semantic deficit Perceptual attributes worse (or better) than functional/associative attributes only for artefacts.		No cases.
Semantic deficit Perceptual and functional/associative attributes evenly impaired for artefacts.	Spared. Not tested or inconclusive.	PL. CN98, ES.
Semantic deficit Data insufficient for determining which type of knowledge is more impaired.	Not tested or inconclusive.	CN94, CW92, JJ, KE, M.LUCIEN, NB, PJ, VER, VP, YOT.
Deficit classified as agnosic	Spared.	DRS.
Deficit classified as lexical	Not tested.	CG, GP98, 7 cases by H. Damasio et al., 1996.

Deficits are classified in terms of the type of category and the type of knowledge (perceptual vs. functional/associative) that are hypothesized to be impaired. The status of patients' structural description system is also reported.

gency tables. These report the frequency of (1) correct and incorrect responses of (2) patients and controls, according to (3) the impairment/ sparing of perceptual and functional/associative knowledge of biological categories. As a minimal approach, the reanalysis considered the percentage correct performance of the patient and the controls for perceptual and functional/associative knowledge of biological category items. The crucial analysis concerns the interaction between the patient/control classification and the type of impaired knowledge, i.e., whether the difference between perceptual and functional/associative knowledge is greater for the given patient than for the control group. Details of these analyses are extensively reported for the relevant cases in Appendix E. These data can be analysed with either a log-linear or a logit-linear model. We are aware that this approach offers only an approximate answer to the lack of a proper experimental design. That is, because this analysis requires that all controls be collapsed into a single cell, it cannot take into account any variation within the normal controls. It is thus possible that a single patient's performance falls within the central 95% of the controls' distribution, while at the same time it is significantly different from the controls' performance when the latter is collapsed into a single data point. Notwithstanding this caveat, we consider significant findings as a suggestive piece of evidence whose reliability can be evaluated within a wider theoretical context. A further comment is necessary regarding the general risk of type II errors: In principle, it is possible that we have at times accepted the null hypothesis (no difference in performance between perceptual and functional/associative knowledge) in some cases where a greater number of stimuli and thus a greater statistical power could have revealed a significant difference. However, the complexity of the statistical design (based on the study of generalised linear models) and the need to consider the significance of interactions makes it impossible to calculate the risk of type II error for this type of analysis.

The result of this critical analysis is a new classification of the reported cases, which may or may not be consistent with that proposed by the authors of the original reports. This new classification and the data in support of it will be considered the core set of facts for interpreting the phenomenon of category-specific deficits.

Table 3 reports the revised classification of those patients presenting a *semantic* deficit. This table will serve as the basis for evaluating different pro-

Table 3(a). *Revised classification of the relationship between the type of category and type of knowledge that is damaged in each patient: Cases with biological categories semantic impairment*

Level of impaired knowledge	*Structural description system*	*Cases*	*Lesion site*
Semantic deficit Perceptual attributes worse than functional/associative attributes for all categories		No cases	
Semantic deficit Perceptual attributes worse than functional/associative attributes only for biological categories	Defective for biological categories	GIULIETTA	MRI: Bilateral T
		MICHELANGELO	CT: Bilateral T, anterior
Semantic deficit Perceptual and functional/associative attributes evenly impaired for biological categories	Spared	EA (2nd 3rd exam)	MRI: Left T
		FM	CT: Left F-T
		JENNIFER	CT: Atrophy of posterior left hemisphere
		SB	CT: Left T (oedema)
	Defective for biological categories	CA	CT: Left sylvian atrophy
		DB	MRI: Diffuse bilateral and mesial T atrophy
		EA (1st exam)	MRI: Left T
		EMMA[a]	MRI: Bilateral T, right more than left
		EW	CT: Left posterior F and P
		GR	CT: Left F-T
		JBR[a]	CT: T-bilateral
		MF	MRI: Right T severe. Left T mildly involved later
	Defective overall	MU	MRI: Bilateral F T; right O
	Not tested	RC	MRI: Bilateral T, left more severe

The classification is based on a critical evaluation of the evidence reported by the authors and, where possible, the results of new analysis of data reported by the authors. The cases are also classified in relation to the integrity of their structural description system. Patients' lesion sites, indicating if the imaging data were derived from CT-scan or from MRI, are also reported.
[a]Artefacts not reliably tested.

posals of the causes of category-specific semantic deficits, and the organisation of conceptual knowledge in the brain.

Table 3 reveals that patients with a disproportionate impairment for biological categories are of three types: (1) patients with a prevailing deficit for perceptual knowledge and impairment in object reality decision for biological category items (Michelangelo and Giulietta); (2) patients with balanced deficits for perceptual and functional/associative knowledge but no impairment in object reality decision (e.g., cases Jennifer and EA, 2nd examination); (3) patients with balanced deficits for perceptual and functional/associative knowledge and impaired object reality decision for biological category items (e.g., cases EW and GR).

As discussed in the Introduction, competing accounts of category-specific semantic deficits make different predictions regarding (1) the types of conceptual knowledge (perceptual vs. functional/associative) that should be impaired given a certain pattern of category-specific deficit, and (2) the semantic categories that should be disproportionately impaired given a certain pattern of impairment of perceptual vs. functional/associative knowledge. Table 3 clarifies the relationship between impaired semantic categories and types of conceptual knowledge. The strongest conclusion is

Table 3(b). *Revised classification of the relationship between the type of category and type of knowledge that is damaged in each patient: Cases with semantic impairment for the domain of artefacts*

Level of impaired knowledge	*Structural description system*	*Cases*	*Lesion site*
Semantic deficit Functional/associative attributes worse than perceptual attributes for all categories		No cases	
Semantic deficit Functional/associative attributes worse than perceptual attributes only for artefacts		No cases	
Semantic deficit Perceptual attribute worse than functional/associative attributes for all categories	Spared	IW	MRI: atrophy of the left T lobe (reduction of the inferior T gyrus)
Semantic deficit Functional/associative and perceptual attributes evenly impaired for artefacts; both spared or evenly impaired for biological categories	Spared	PL	MRI: Left F-T atrophy
	Defective for artefacts	No cases	
	Defective overall	No cases	
	Not tested or inconclusive	CN98	MRI: Left anterior and inferior mesial T.
		ES	MRI: Bilateral atrophy of inferior T lobes, more extensive on the right.

The classification is based on a critical evaluation of the evidence reported by the authors and, where possible, the results of new analysis of data reported by the authors. The cases are also classified in relation to the integrity of their structural description system. Patients' lesion sites, indicating if the imaging data were derived from CT-scan or from MRI, are also reported.

that impairment of specific semantic categories is *not* associated with damage to a particular type of conceptual knowledge (perceptual vs. functional/associative). Our reanalysis shows that a disproportionate deficit for perceptual knowledge restricted to biological categories is only found in two cases, Giulietta and Michelangelo,[1] while in 11 cases perceptual and associative knowledge are impaired to equivalent degrees. Furthermore, the only case of global impairment for visual-perceptual knowledge (case IW) presented a relative impairment for artefacts (although the effect was not impressive). This pattern of results is clearly inconsistent with the classical SFT account of the causes of semantic category-specific deficits.

For those cases presenting a prevailing semantic deficit for biological categories, object reality decision was impaired in 11 cases and was spared in 4. Therefore, damage to pre-semantic visual knowledge is *not* required for disproportionate impairment of the biological categories. This finding is inconsistent with models which assume that a disproportionate deficit for living things arises because the structural descriptions of their category members are more similar to each other than those of nonliving things, and thus more susceptible to error when the structural description or the semantic system is damaged (e.g., Humphreys & Forde, 2001). Furthermore, Table 3 clearly demonstrates that an impairment for object reality decision is not necessarily associated with an impairment for semantic perceptual knowledge compared to functional/associative knowledge. Only in cases Giulietta and Michelangelo was a disproportionate impairment for perceptual knowledge observed; however, in nine cases the

[1] These two patients were examined in the same laboratory, and presumably with the same materials. It should also be noted that in our statistical reanalysis of the published data, we have decided to ignore certain weaknesses inherent in the experimental design. Therefore, this pattern is in strong need of confirmation with fresh data.

impairments for perceptual and associative knowledge were equivalent.

Although the great majority of cases presenting reliable category-specific dissociations can be interpreted as deficits arising at the semantic level (as indicated, for example, by the fact that they are impaired in verifying property statements), for some cases the respective authors have suggested a pre-semantic or post-semantic level of impairment. Here we briefly consider these cases (but see Appendix E for details).

Are there cases of category-specific agnosia? Some authors have suggested that category-specific impairments can originate at early ("apperceptive") stages of visual perception. Funnell (2000) hypothesised that case NA suffered from apperceptive category-specific agnosia. However, the category effect in naming was not strong and the pictorial stimuli from biological and artefact categories were not strictly matched for their visual characteristics. For cases FS, MS, and MrW experimental data are insufficient to support clear interpretation, and the reader is referred to Appendix E for discussion of those cases.

HJA was classified as a case of "integrative agnosia". The evidence in favour of an agnosic deficit is not direct but is based on the observation of a category-specific impairment in picture naming (and drawing from memory) combined with relatively intact semantic knowledge. The authors considered the "contour overlap" of the pictures (supposedly greater for biological items) as the critical variable responsible for the observed category effects. However, our reanalysis of the reported data is not in line with this claim. We have also reconsidered the purported role of contour overlap in other cases (JB, SRB) with a similarly negative conclusion (see also case NA, Appendix E).

The case study of ELM focused on fine-grained aspects of a purported visual perception deficit for biological stimuli. On the whole, an agnosic component of the category-specific deficit is probable, but a semantic deficit for the same categories cannot be excluded. This case has some similarity to the cases Michelangelo and Giulietta, for whom the respective authors have indicated the structural description system to be the locus of the observed category-specific effects. We do not have an articulated theory of the relationship between the "structural description system" (generally considered to be a pre-semantic, modality-specific cognitive stage) and stored perceptual knowledge, which can be directly accessed through the verbal system. Therefore, it is not clear whether these cases present agnosic or semantic deficits.

With respect to cases presenting a possible agnosia for artefacts, DRS was classified as having associative agnosia for objects, but this conclusion is weakened by the fact that "nuisance" factors were not strictly controlled for the different categories.

Summing up, claims about the existence of category effects at an early perceptual level are not given clear support by our critical review. Category discrepancies in naming by patients affected by visual agnosia do not exclude the possibility that a semantic deficit coexists with their visual disorder.

Are there cases of category-specific anomia? Evidence supporting the existence of category-specific anomia will necessarily be weak, since it mainly rests on negative findings about possible pre-semantic or semantic impairments. We cannot exclude the possibility that in such cases a subtle semantic deficit was not detected due to the relatively low difficulty of comprehension tasks (relative to production tasks). This conclusion applies to cases Dante and TU, who presented impairments for biological categories, and to case GP98, who presented the opposite dissociation. For cases MD and CG see comments in Appendix E. Thus, although category-specific anomias are certainly theoretically possible (perhaps reflecting disconnection from semantics to the lexical system or systems) evidence for their existence is not particularly strong.

What are the categories of category-specific deficits?

In this section we discuss which categories are impaired in category-specific semantic deficits. This general point includes a number of distinct issues, which will be discussed under separate headings. We begin by considering the "grain" of category-specific deficits. We address the issue of whether there is convincing evidence for further fractionations within the categories of living and nonliving things. We also consider the status of the categories "food," "musical instruments," and "body parts." This seemingly arbitrary selection of categories for special consideration has empirical and theoretical motivations. On the empirical side, it has been observed that these categories appear to violate the living/nonliving dichotomy. For example, it has been claimed that musical instruments tend to be impaired in patients with damage to the category living things. On the theoretical side, it has been claimed that deficits that appear to be category-specific in nature are really deficits to noncategorical, modality-based conceptual knowledge subsystems that disproportionately affect all categories that are differentially dependent on those subsystems. Therefore, the putative association of, for example, musical instruments and living things is of great theoretical significance.

Is there evidence for further fractionations within the biological and artefact domains?

The study of category-specific deficits has focused mainly on the contrast between biological and artefact categories. However, the stimuli from these categories are not always comparable from one study to another (see Appendix A). With respect to biological categories, nearly all authors have included animal stimuli; some authors indicate as animals only the subset of "four-legged animals," and separately consider insects, birds, and fish. Less consistently, plant life has been included in the category living things, generally comprised of fruit and vegetables, and more rarely flowers. With respect to artefacts, the stimuli employed most often include tools, vehicles, and furniture, and less consistently, kitchen utensils and clothing.

Generally, authors have not explicitly addressed the issue of homogeneity within the domains of biological and artefact categories. Because of this, the number of stimuli employed from each sub-category have seldom allowed for fine-grained comparison within the broad domains of biological and artefact categories. However, there are now a number of cases that seem to show fine-grained dissociations. Table 4 reports those cases presenting with dissociations within the biological category, sorted on the basis of the degree of evidence. Two points are relevant. First, there is a double dissociation between an impairment for animals and an impairment for plant life. Second, a severe deficit for fruit and vegetables has been reported only for male patients (eight males, i.e., MD, EA, JJ, ELM, GR, JV, SRB, TU); for the category animals no clear gender effect emerges (two females, i.e., EW, LA; two males, i.e., LH, KE). We will return to this point below.

Within the domain of nonliving categories, YOT shows a trend toward a more severe impairment for small manipulable "indoor" objects compared to large outdoor objects. However, this case is extremely complicated and presents with different category patterns across different tasks.

Table 4. *Evidence for further fractionation within the biological domain*

	Strong evidence	*Possible evidence or trend*
Animals more impaired than fruit and vegetables.	EW selective impairment of animals.	LA LH KE relative preservation of fruit and vegetables.
Fruit and vegetables more impaired than animals.	MD selective impairment of fruit and vegetables. EA substantial impairment of fruit and vegetables. JJ substantial advantage for animals.	ELM GR JV SRB TU

The status of the categories "food," "body parts," and "musical instruments"

The category "food" includes both naturally occurring items as well as manufactured food. It is thus of theoretical interest whether the category food behaves like other "natural" categories. Interest in this issue is also motivated by the observation, especially in the early studies of category-specific deficits, that an impairment for the category "food" is often associated with an impairment for living things (see Appendix C). In order to deconfound the category "food" from other natural categories, for instance, fruit and vegetables, we will limit our discussion to those studies in which the category "food" did not include fruit and vegetable stimuli in the form that they naturally appear. A reliable impairment for the category "food" was observed in Felicia, JBR, and SB, all of whom also presented with a general impairment for biological categories. Furthermore, in case JJ, who presented a selective sparing of animals, performance on the category "food" was similar to performance on fruit and vegetables—both categories were impaired. These findings would suggest that the category "food" has a deep similarity to fruits and vegetables. However, in both case MD, who presented a reliable impairment for fruit and vegetables, and case PS, who was impaired for animals and vegetables, food was spared. Thus, it would seem that impairment for the category of food dissociates from impairment for biological categories such as animals and fruit and vegetables. The question concerning the nature of the broader category "food" remains open.

The a priori classification of body parts and musical instruments seems to be unequivocal: Strictly speaking, body parts are natural items and musical instruments are artefacts. However, authors who have studied these stimuli in semantically impaired patients have often been puzzled by the observation that performance for these two categories of objects can dissociate from performance on biological and artefact categories, respectively. Somewhat paradoxically, it has been suggested that musical instruments are similar to living category items, since the ability to identify musical instruments, it is argued, depends upon their visual attributes (Dixon, Piskopos, & Schweizer, 2000). It has also been suggested, paradoxically, that body parts are more similar to artefacts, since, it has been argued, both body parts and artefacts depend upon functional/associative information for their identification (Warrington & McCarthy, 1987).

The suggestion of a close relationship between musical instruments and biological categories on the one hand, and body parts and artefacts, on the other, is primarily based on cases presenting a prevailing deficit for biological categories, with less impaired or even normal performance on body part stimuli. In Appendix D we report data for only those patients who presented with a deficit for body parts as well as a dissociation between living and nonliving things. It should be emphasised that the statements reported in this appendix are based on inspection of the reported data; the labels "spared/impaired" do not necessarily endorse the conclusion that a real effect is actually present or would survive covariance for the relevant "nuisance" variables.

If there actually is an association between body parts and artefacts, then those cases presenting a prevailing impairment for artefacts should also present a greater impairment for body parts compared to biological categories. An inspection of the literature does not offer convincing evidence that body parts are systematically more impaired than biological categories in these patients: cases GC, GP98, and PL presented a disproportionate impairment for artefacts, but were not correspondingly impaired for body parts.

The relationship between musical instruments and biological categories is even less uniform: there are cases of impairment for biological categories where performance on musical instruments is at, or near, the normal level (BD, CW, EW, Felicia, and SE), and cases where performance falls near the level for biological categories, or even at a lower level (see Appendix D). With respect to the opposite dissociation, in which performance for biological categories is better than for artefacts, there are cases that present with poor performance on musical instruments (CG, CW92, PL, SM, YOT). Only for case GP98 was the naming impairment for musical instruments intermediate between that for artefacts and that for biological categories.

On the whole, if any definite point emerges for the categories of body parts and musical instruments from the literature on semantic memory patients, it is that body parts tend to be spared and musical instruments tend to be impaired beyond the biological categories/artefacts dissociation. As a consequence, other factors that might influence the pattern of patients' performance should be taken into account in order to allow a clearer interpretation of the status of these two categories. The relationship between the categories "musical instruments" and "body parts" and the domains "living things" and "nonliving things" has recently been investigated by Barbarotto, Capitani, and Laiacona (2001), by means of a latent variables analysis carried out on a sample of semantically impaired patients. In line with the impression drawn from the literature, the raw mean performance of the patients in this study indicate that body parts are the most preserved category while musical instruments are the least preserved category. However, after covariance, this profile was no longer observed; the result can be explained at the group level as arising from the influence of unmatched "nuisance" variables, such as age of acquisition and lexical frequency. This does not of course exclude the possibility that, in single cases, there may be selective impairment or sparing of body parts (see Shelton, Fouch, & Caramazza, 1998, for discussion). However, the outcome of the latent variables analysis indicated that body parts were related only to artefacts, and that musical instruments showed a significant relationship to artefacts but only a marginal relationship to biological categories. For more in-depth discussion of these findings, the readers are referred to the original paper.

An association between impairment for biological categories and impairment for other categories has been suggested (e.g., with precious stones for case JBR) but is not supported by sufficient experimental evidence. More recently, Borgo and Shallice (2001) reported case MU, who was impaired for biological categories as well as for the "sensory quality" categories (liquids, edible substances, materials). However, this pattern of association, too, is not a necessary one since sensory quality categories dissociate from biological kind objects in at least one patient, EA (Laiacona, Capitani, & Caramazza, in press).

DISCUSSION

Neuropsychological investigations provide one of the richest sources of data for constraining theories of normal cognition and its possible neural basis. Practice and analysis have shown that the methodology of single-patient investigation generates the most reliable observations for this purpose. Nonetheless, as for any method, there are intrinsic limitations that must be considered when interpreting data from single-patient reports. These limitations are well known (Caramazza, 1986). Because patients are experiments of nature, we do not have control over the exact transformations to the cognitive system introduced by brain damage. This means that replication is pragmatically of limited utility in this type of research: patients present with varying degrees of severity, clinical profiles may evolve rapidly, and the configuration of noncritical cognitive deficits and associated brain lesions vary considerably across patients. This last feature is crucial, since it ends up constraining the tasks that can be administered to any given patient, thus making it impossible to "replicate" tasks used with other, similar patients. The end result is that the cases relevant to a theoretical issue consist of many "partial" experiments, since there are always questions that remain open given alternative theoretical perspectives. And, yet, we have no choice but to consider the set of partial experiments as they are given to us. For the reasons listed above, there is no simple way to "complete" the experiments. Nonetheless, within the set of potentially useful case studies we can distinguish those that are theoretically useful from those whose status is more problematic. This is what we have tried to do in this critical review. We have pulled out from the large set of patients with semantic category-specific deficits those studies which present data that are statistically reliable on tasks that tap the integrity of perceptual and functional/associative knowledge. In the end, the most useful way to determine the theoretical value of a single case study is not the mere, faithful "replication" of the case (which would clearly be important but, as pointed out, may be pragmatically nearly impossible) but an assessment of the pattern of results obtained across theoretically relevant cases. That is, convergence of results rather than straight replication is the more realistic tool available to researchers working with neurological cases.

The picture that emerges from our critical review of the published cases has the following general contour—we say "contour" because, as we will argue below, the internal details of the picture remain unclear. The most reliable form of semantic category-specific deficit is found for the domain of biological objects.[2] However, this domain fractionates into two independent semantic categories: the categories of animals (animate objects) and fruits and vegetables (inanimate biological objects) can be damaged/spared independently of each other. Furthermore, although impairment of the biological domain is often associated with impairment to the categories of manufactured foods and musical instruments, these associations are *not* necessary. The category of body parts clearly dissociates from animals and fruits and vegetables, and is most often impaired together with artefacts. However, there are case reports (see Appendix D) confirming the dissociation of this category from the domain of artefacts (see also Shelton et al., 1998, for such a case and review of other relevant cases). No reliable fractionations have been reported for the domain of artefacts (see critical review of YOT in Appendix E). Therefore, in answer to the question "What are the categories of category-specific semantic deficits?" the most cautious answer would seem to be "the categories of animate objects, inanimate biological objects, and artefacts."

The other major question addressed in this review concerns the relationship between type of category-specific deficit and type of conceptual knowledge deficit. More specifically, the question concerns whether there is a necessary association between impairment to the domain of biological objects and impairment to knowledge of the visual properties of objects, and between impairment to the domain of artefacts and impairment to knowledge of the functional/associative properties of objects. The results of our review are clear on one aspect of this question: Types of category-specific deficits are *not* associated with specific types of conceptual knowledge deficit. In fact, the vast majority of patients with category-specific deficit for biological objects are equally impaired for visual and functional/associative properties of objects.

The facts that have emerged from our critical review of the cases of category-specific deficits have clear, if limited, implications for theories of the causes of these deficits. First, the categories of category-specific deficits are far more fine-grained than predicted by SFT accounts. That is, there is convincing evidence that the domain of living things fractionates into two distinct domains: animate objects and the domain of fruit and vegetables. Second, category-specific deficits are generally associated with uniform damage to conceptual knowledge independently of whether such knowledge concerns form, function, or other conceptual properties of objects. These results are clearly inconsistent with core expectations derived from SFT accounts; they are somewhat problematic for OUCH-type theories; but they are fully consistent with evolutionarily based domain-specific accounts.

As noted in the Introduction, SFT-type accounts predict that the categories of category-specific deficits are determined by the type of conceptual knowledge that is damaged in a given patient. Of particular relevance here is the claim that damage to "visual semantic" representations will necessarily result in disproportionate difficulty for living things, as well as other categories such as musical instruments that presumably also depend crucially on this type of conceptual knowledge for distinguishing among the members of the category. Thus, the SFT predicts the necessary co-occurrence of damage to animals, fruit/vegetables, musical instruments, and sensory quality categories (liquids and substances) (e.g., Borgo & Shallice,

[2] This type of dissociation is more frequent among males than females. Considering cases affected by prevailing biological categories deficit and by a disease whose incidence is not related to gender such as herpetic encephalitis, males were 21/28, and this proportion is significantly different from chance (p = .006).

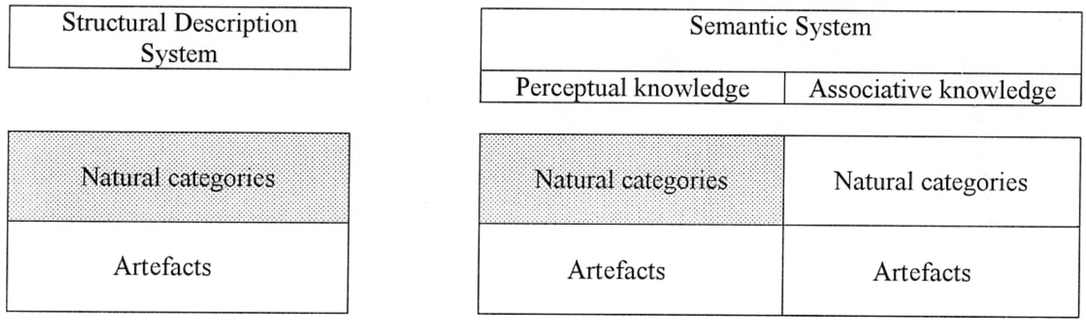
2001). The fact that the categories animals and fruit/vegetables can be damaged independently of each other is highly problematic for SFT accounts. Also highly problematic for these theories is the fact that selective impairment for living things is not associated with disproportionate impairment for visual relative to other types of object knowledge.

The pattern of results that have emerged from our review are not entirely consistent with OUCH-type accounts. To be sure, these accounts correctly predict that category-specific deficits should not necessarily result in greater damage for one type of conceptual knowledge (i.e., visual vs. functional) than another. However, they fail to predict the disproportionate occurrence of category-specific deficits for the biological categories. By contrast, the latter two results are exactly as predicted by the Domain-specific theories. The latter class of theories assume that the domains of biological kinds have a special status in virtue of their fundamental evolutionary value. Although the picture of the empirical facts about category-specific deficits that we have painted is clear in its outlines, the details remain indistinct and uncertain. For example, the relationship between impairment to manufactured and natural foods remains unresolved, although there are indications that the two may dissociate. Also problematic for interpretation is the fact that all the reported cases presenting greater difficulty for fruit/vegetables than for animals were males, and it has been observed that relative to women, men are less familiar with fruit and vegetables than they are with animals. For a broader discussion of gender effects, see Barbarotto, Laiacona, Macchi, and Capitani (2002). More importantly, the relationship between impaired category and impaired type of knowledge is rather complicated. The complication comes from the fact that three distinct patterns of relationship between knowledge of object form and type of impaired category have been reliably documented. These patterns are schematically represented in Figure 1. The first pattern corresponds to selective deficits in object decision and in conceptual knowledge about the perceptual properties of living things. The second pattern corresponds to uniform damage to conceptual knowledge pertaining to the properties of biological kind objects, but spared ability to make object decisions for all objects. The third and most common pattern consists of selective damage to the category biological objects in object decision tasks and impairment for all types of conceptual knowledge about those objects.

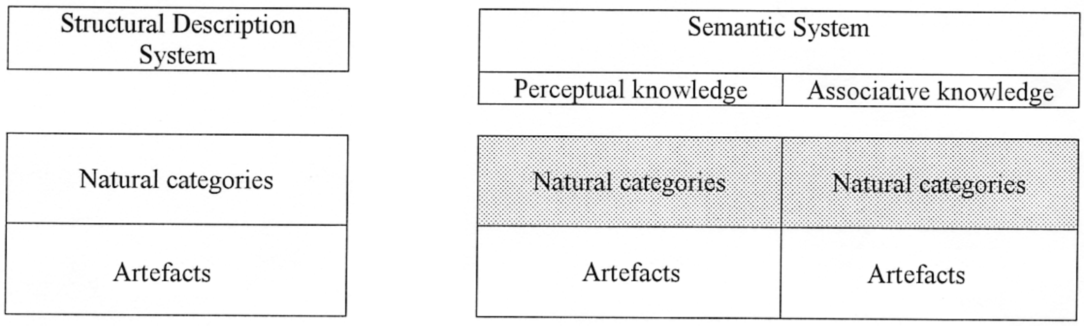
Difficulties in object decision tasks have typically been interpreted as reflecting damage to the structural description system—a system that represents the visual form of objects for recognition. Available data indicate that the structural description system is organised into separate domains of knowledge such that they can be damaged independently of each other (see Table 3). This view entails the existence of pure category-specific agnosias, but our review has failed to find such cases (that are statistically reliable). Moreover, the different patterns of deficits in the object decision and conceptual knowledge tasks suggest that the structural description system functions relatively autonomously from conceptual knowledge about object form. This conclusion is motivated by the fact that there is no necessary association between difficulties in object decision and conceptual knowledge tasks, whether the latter tap knowledge about object form or their function: In particular, the same pattern (balanced semantic impairment of perceptual and functional/associative knowledge) can coexist with the sparing and with the impairment of the structural description system. However, two cases in which the structural description system was damaged in a categorical fashion (Michelangelo and Giulietta) were apparently affected by selective damage to perceptual semantic knowledge of biological categories in association with damage to the structural descriptions of the same categories. Some authors (Sartori & Job, 1988) have interpreted the latter pattern as indicating that the integrity of the structural descriptions of biological objects is necessary for the integrity of the semantic knowledge of the perceptual attributes of those objects.

This hypothesis has interesting implications. If the pattern of performance characterised by category-specific object decision impairment and modality-independent conceptual knowledge impairment (e.g., cases EW, GR, etc.) were to

A. Perceptual attributes worse than associative attributes only for natural categories: Structural description impaired only for natural categories (Giulietta and Michelangelo)



B. Balanced deficit for perceptual and associative attributes of natural categories: Structural description spared (EA 2nd–3rd, FM, Jennifer, SB)



C. Balance between the deficit for perceptual and associative attributes of natural categories: Structural description impaired for natural categories (CA, DB, EA 1st, Emma*, EW, GR, JBR*, MF, MU; * = artefacts were not reliably tested in the object reality decision)

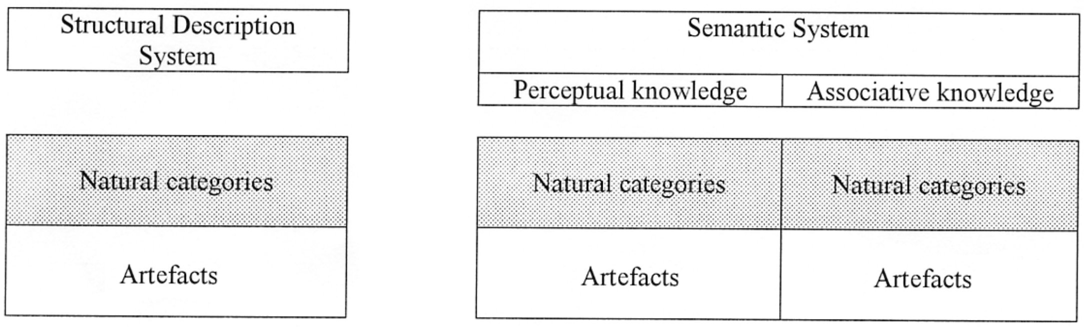


Figure 1. *Deficits of perceptual and associative attributes.*

result from damage to both a categorically organised structural description system and a categorically organised homogeneous semantic system, it would be reasonable to expect that (1) these patients would in general be affected by a semantic deficit that is more severe for perceptual than functional/associative semantic knowledge, and (2) that they would tend to show more severe deficits in naming objects than patients with damage to only the conceptual system (e.g., patients FM, Jennifer, etc.). The analysis of the type of semantic impairment and of the severity of naming impairment across subgroups of patients (see Appendix F) failed to show this pattern of results: After angular transformation, the mean severity of the group with no damage to the structural description system (38. 6% correct) was not milder than the mean severity of the group with damage to the structural description system (44. 12% correct). This difference was not significant, $t(10) < 1$, n.s.

In conclusion, there are two clear facts that have emerged from this investigation of semantic category-specific deficits. First, the domain of biological kinds can be damaged independently of all other semantic categories tested and, furthermore, this domain of knowledge further fractionates into animate and inanimate domains. Second, the vast majority of category-specific semantic deficits typically involve to equal degrees all types of object properties (perceptual and functional/associative) in the affected categories. Theories of the organisation of conceptual knowledge that cannot account for these facts must be considered with suspicion.

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APPENDIX A

Cases presenting a category dissociation

We report all the cases to our knowledge that showed a category dissociation in picture naming or in any other task. We did not consider cases whose data were not clearly reported or submitted to a statistical analysis even if they could potentially be relevant (e.g., Laurent et al., 1990, Case 9; Goldenberg, 1992; Damasio, 1990). In section 1 are grouped the single cases showing a prevailing natural categories impairment and in section 2 cases presenting a prevailing artefacts impairment. For the complete reference see Appendix E. Cases of finer-grained dissociations within biological categories are italicised (strong evidence) or underlined (possible evidence; see also Table 4).

1. Primary biological categories impairment

Case/Authors	*Age, gender*	*Disproportionately impaired categories*	*Aetiology*	*Lesion site*
BD Hanley et al., 1989	55, M	Animals, fruit and vegetables	HSE	Right T (posterior part of superior T gyrus)
C (CW97) Wilson, 1997; Wilson et al., 1995	46, M	Animals (other biological categories not examined)	HSE	Bilateral: T poles, hippocampus, amygdala, Mam-b; Left: inferior, middle and superior T gyri, insula, medial F, striatum; Right: inferior T gyrus, insula.
CA Capitani et al., 1993	68, M	Biological categories (animals, fruit and vegetables not analysed separately)	Progressive aphasia	Left sylvian atrophy
DANTE Sartori et al., 1993a	22, M	Animate (not further specified)	Encephalitis	Not reported
DB Lambon Ralph et al., 1998	86, F	Animals (fruit and vegetables not tested in most tasks)	DAT	Bilateral general and mesial T atrophy
DM94 Breedin et al., 1994a, 1994b	56, M	Animals, insects (fruit and vegetables not tested) + musical instruments	Focal degenerative	MRI = normal SPECT = inferior T-O (more severe to left)
DM97 Humphreys et al., 1997	44, F	Animate stimuli (not further specified)	Brain abscess	Left medial and inferior T-O
EA Barbarotto et al., 1996; Laiacona et al., 1997	47, M	Biological categories (animals, fruit and vegetables not analysed separately) and musical instruments. After 9 years animals and musical instruments were still defective, but less impaired than fruit and vegetables	HSE	Left T: middle, inferior, fusiform and lingual; parahippocampal gyrus was spared, partial involvement of hippocampus
EC Carbonnel et al., 1997	55, M	Animals (plants slightly impaired)	Anoxia	No lesion on MRI
ELM Arguin et al., 1996; Dixon, 1999; Dixon & Arguin, 1999; Dixon et al., 1997; Takarae & Levin, 2001	68, M	Fruit and vegetables; animals less severe	Stroke	Bilateral inferior T
EMMA Gentileschi et al., 2001	60, F	Biological (not further specified)	Focal degeneration	Bilateral infero-polar T, right more severe than left

Case/Authors	*Age, gender*	*Disproportionately impaired categories*	*Aetiology*	*Lesion site*
EW Caramazza & Shelton, 1998	72, F	Animals (sparing fruit and vegetables and all the other categories)	Stroke	Left posterior F and P
FA Barbarotto et al., 1996	56, M	Biological categories (animals, fruit and vegetables not analysed separately)	HSE	Left T lateral, mainly middle and inferior; Right F, rectus and cingulate gyri
FB Sirigu et al., 1991	19, M	Animals and food	HSE	Bilateral T: pole and inferior neocortex, hippocampus, amygdala
FELICIA De Renzi & Lucchelli, 1994	49, F	Biological categories (animals, fruit, vegetables and flowers) + food	HSE	Left F-T and insula; right T-insula
FI Barbarotto et al., 1996	68, M	Biological categories (animals, fruit and vegetables were not analysed separately)	HSE	Left T (hippocampus, parahippocampus and basal), insula and F basal; right deep peri-ventricular white matter
FM Laiacona et al., 1993	20, M	Biological categories (animals, fruit and vegetables not analysed separately) and musical instruments	Head injury	Left F-T
FS Dixon et al., 2000	50, M	Animals and musical instruments (four items each) (other LC categories not tested)	HSE	Not reported
GC Cardebat et al., 1996	72, F	Animals (fruit and vegetables not tested)	Progressive aphasia	Left T atrophy, mesial and posterior
GIULIETTA Sartori et al., 1993b	55, F	Animals (fruit and vegetables in a preliminary test)	HSE	Bilateral T and hippocampus
GP97 Gonnerman et al., 1997	61, M	Biological (fruit and vegetables) more impaired than artefacts (furniture, vehicles, clothing, weapons). Animals not included	DAT	Mild cerebral atrophy consistent with the subject's age
GR Laiacona et al., 1993	22, M	Biological categories (animals, fruit and vegetables not analysed separately, *but possible greater impairment of fruit and vegetables*). Musical instruments impaired	Head injury	Left F-T
HELGA Mauri et al., 1994	60, F	Animals and vegetables (not analysed separately)	DAT	No atrophy on CT-scan
HJA Riddoch & Humphreys, 1987a; Riddoch et al., 1999	61, M	Animals, fruit and vegetables (and body parts, see comments)	Stroke	Bilateral inferior T, OT, fusiform, lingual
IL Lecours et al., 1999	75, M	Biological items	HSE	Not reported
ING Warrington & Shallice, 1984	44, F	Animals, food	HSE	T-bilateral
JB Riddoch & Humphreys, 1987b; Humphreys et al., 1988	45, M	Animals, fruit and vegetables. Their impairment on picture naming was balanced. Body parts were relatively spared.	Head injury	Left PO

Case/Authors	*Age, gender*	*Disproportionately impaired categories*	*Aetiology*	*Lesion site*
JBR Warrington & Shallice, 1984; Bunn et al., 1997; Funnell & De Mornay Davies, 1996; Wilson, 1997	23, M	Biological categories and foods. Musical instruments impaired and body parts spared in a word definition task	HSE	T-bilateral
JENNIFER Samson et al., 1998	22, F	Animals, fruit, vegetables (not significantly different)	Head injury	Atrophy of posterior L hemisphere
JH Swales & Johnson, 1992	53, M	Animals, fruit and vegetables	HSE	Left T
JMC Magniè et al., 1999	58, M	Animals, fruit, vegetables, musical instruments	Post-anoxic	CT-scan: no lesion
JV Pietrini et al., 1988	47, M	*Plants (more severe than animals)*	HSE	Left: anterior and middle T, F basal, insula; Right: insula
KB Warrington & Shallice, 1984	60, F	Animals, food	HSE	T-bilateral, left more severe
KG Wilson, 1997	27, F	Animals (other natural categories not examined) and musical instruments	Head injury	Left T antero-lateral, P inferior
KR Hart & Gordon, 1992	70, F	Animals (see Appendix E)	Para-neoplastic	Diffuse, especially T lobes bilaterally
LA Silveri & Gainotti, 1988; Gainotti & Silveri, 1996	54, F	*Animals possibly more severe than flowers. Fruit and vegetables.* Food intermediate (1st exam), more severe at 2nd exam. Musical instruments (2nd exam) impaired	HSE	Bilateral inferior T (L more severe). On the left: hippocampus and amygdala.
LF Barbarotto et al.,1996; Laiacona et al., 1997	43, M	Biological categories (animals, fruit and vegetables), not analysed separately	HSE	Left whole T, part of F, hippocampus, and parahippocampal gyrus. Right: T basal, fusiform and parahippocampal gyrus
LH Farah et al., 1989, 1991, 1996; Etcoff et al., 1991; Takarae et al., 2001	36, M	Biological categories: *more severe with animals*, probably intermediate with fruit and vegetables (Etcoff et al.). Musical instruments intermediate and body parts just mildly impaired	Head injury	Right: very severe T and F; Left: subcortical O-T; bilateral P-O
MB Farah et al., 1991, 1996; Takarae et al., 2001	30, F	Biological categories (not further distinguished). Musical instruments intermediate and body parts spared	Head injury	Left T swelling, without focal damage
MC Teixeira Ferreira et al., 1997	59, M	Animals (other natural categories not tested)	Stroke	Left medial-inferior T; right inferior T
MD Hart et al., 1985	34, M	Fruit and vegetables (other categories spared, including animals and food)	Stroke	Left F and basal ganglia
MF Barbarotto et al., 1995	60, M	Biological categories (animals, fruit and vegetables not analysed separately). Musical instruments were intermediate	Progressive focal degeneration	Right T severe atrophy, involving hippocampus and parahippocampal gyrus. Left T mildly involved later

Case/Authors	Age, gender	Disproportionately impaired categories	Aetiology	Lesion site
MICHELANGELO Sartori & Job, 1988; Sartori et al., 1993a, 1993b, 1994a, 1994b; Mauri et al., 1994	38, M	Animals and vegetables	HSE	T anterior, bilateral
MS Young et al., 1989; Mehta et al., 1992	41-43, M	Biological categories	HSE	Bilateral T-O
MU Borgo & Shallice, 2001	30, M	Biological categories, liquids, edible substances, nonedible materials	HSE	Bilateral T lobes and F lobes (medial portions); right O lobe (medial portion)
NA Funnell, 2000	70, F	Possible greater impairment of biological categories (especially insects)	DAT	Bilateral T-P atrophy (more marked on the right)
NR De Haan et al., 1992	29, M	Biological categories	Head injury	Right P and left T-P
NV Basso et al., 1988	73, M	Biological categories and musical instruments	Progressive aphasia	Left T atrophy
PR Teixeira Ferreira et al., 1997	69, M	Animals (other biological categories not tested)	HSE	Left medial-inferior T; right inferior T
PS Hillis & Caramazza, 1991	45, M	Animals and vegetables (fruit intermediate, foods spared)	Head injury	Bilateral T subdural haematoma; left F haematoma; right F epidural haematoma
RC Tyler & Moss, 1997; Moss et al., 1998	37, M	Animals, fruit and vegetables (balanced impairment)	HSE	Bilateral T, left more severe
RM Pietrini et al., 1988	23, M	Animals and plants	HSE	Left T and F basal
SB Sheridan & Humphreys, 1993	19, F	Animals, food (including fruit and vegetables)	HSE	Left T oedema
SBY Warrington & Shallice, 1984	48, M	Biological categories and food	HSE	Bilateral T
SE Laws et al., 1995; Laws, 1998; Moss et al., 1997	60, M (left-handed)	Biological categories (main focus on animals)	HSE	Left nearly normal (slight signal alteration on uncus and amygdala); right: inferior and lateral T, uncus, hippocampus, parahippocampal gyrus, insula
SRB Forde et al., 1997; Humphreys et al., 1997	38, M	Biological categories (*fruit and vegetables probably more impaired than animals*)	AVM haemorrhage	Left: T (inferior medial), O; right: Thalamic infarction
TOB McCarthy & Warrington, 1988, 1990; Parkin et al., 1993	63, M	Biological categories (not further split) were disproportionately impaired only in a spoken names definition task	Progressive aphasia	Left T (at PET scan)

Case/Authors	*Age, gender*	*Disproportionately impaired categories*	*Aetiology*	*Lesion site*
TS Wilson, 1997	31, M	Animals (other biological categories not examined)	Head injury	Generalised atrophy, especially left superior T
TU Farah & Wallace, 1992	51, M	*Fruit and vegetables (animals probably intermediate)*	AVM haemorrhage	Left O
VG Teixeira Ferreira et al., 1997	48, F	Animals (other biological categories not tested)	HSE	Left medial-inferior T
MR. W Rumiati et al., 1994; Rumiati & Humphreys, 1997; Farah, 1997	88, M	Biological categories ("structurally similar categories") inconsistently worse	?	Cerebral and cerebellar atrophia

2. Primary artefacts impairment

Case/Authors	*Age, gender*	*Disproportionately impaired categories*	*Aetiology*	*Lesion site*
CG Silveri et al., 1997, 2000	66, M	Artefacts more impaired than biological items or animals. Artefacts were not explicitly contrasted. Musical instruments were very close to artefacts	Progressive atrophy	Left T
CN94 Breedin et al., 1994a	Not reported	Tools more impaired than animals	Stroke	Left FP
CN98 Gaillard et al., 1998	25, F	Impaired artefacts (on naming: not further distinguished; on the questionnaire: tools). Spared biological items (on naming: not further distinguished; on the questionnaire: fruit and vegetables)	HSE	Left anterior and infero-mesial T
CW92 Sacchett & Humphreys, 1992	39, M	Artefacts (not analysed at a finer level of fractionation) and musical instruments more impaired than animals	Stroke	Left FP
DRS Warrington & McCarthy, 1994	59, M	Common objects more impaired than animals, vehicles, and flowers	Stroke	Right P and left OT
ES Moss & Tyler, 1997, 2000	67, F[a]	Artefacts more impaired than biological categories, without further distinction	Progressive aphasia	Cerebral atrophy, inf T lobes bilaterally more extensive on the right
GP98 Cappa et al., 1998	27, M	Tools, furniture, more impaired than vehicles, musical instruments, vegetables and animals; Fruit and body parts probably spared on naming	Bleeding of AVM plus polectomy	Left anterior T
IW Lambon Ralph et al., 1998	53, F[b]	Artefacts more impaired than biological categories (no further distinguished)	Progressive degeneration	Atrophy of the left T lobe
JJ Hillis & Caramazza, 1991	67, M	The categories different from animals, i.e., vegetables, fruit, food, body parts, clothing, furniture; transportation was intermediate	Stroke	Left T and basal ganglia

Case/Authors	*Age, gender*	*Disproportionately impaired categories*	*Aetiology*	*Lesion site*
KE Hillis et al., 1990	52, M	Taking into account the mean percentage of errors over 6 tasks, body parts, furniture and clothing were the most impaired, whereas food, *vegetables and fruit the least, water animals, transport, other animals and birds intermediate*	Stroke	Left F-P
M. LUCIEN Hécaen & De Ajuriaguerra, 1956	64, M	Artefacts	Neoplasia	Left mesial O, extending to P and slightly to T lobe
NB Gonnerman et al., 1997	80, F	Artefacts (furniture, vehicles, clothing, weapons) more impaired than biological items (fruits and vegetables), without distinction within artefacts and biological items.	DAT	Mild cerebral atrophy
PJ Breedin et al., 1994a	Not reported	Tools more impaired than animals	Stroke	Left FP
PL Laiacona & Capitani, 2001	76, F	Artefacts (tools, furniture, and vehicles not analysed separately) more impaired than biological categories (animals, fruit and vegetables not analysed separately). Musical instruments were the worst category	Progressive aphasia	Left: FT atrophy
SM Turnbull & Laws, 2000	84, M	According to the authors, on naming artefacts are more impaired than biological items. Nonliving and biological categories data are further fractionated, but data are not analysed; musical instruments were the worst category	Infarction	Right: posterior and inferior OT region, thalamus and internal capsule
VER Warrington & McCarthy, 1983	68, F	Objects more impaired than food, flowers and animals; no further distinction between subtypes of objects	Stroke	Left: FP
VP Breedin et al., 1994a	Not reported	Tools more impaired than animals	Stroke	Left FP
YOT Warrington & McCarthy, 1987	50, F	*Small manipulable objects* and furniture, body parts more impaired than large man-made objects and animals, occupation, vegetables, fabrics. Musical instruments were also impaired	Stroke	Left TP

[a]Left-handed. [b]Ambidextrous?

APPENDIX B

Other cases from group studies not included in the database

1. Primary biological categories impairment[a]

Cases/Authors	*Disproportionately impaired and spared categories*	*Etiology*	*Comments*
No. 1, 2, 3, 4, 5, 6, 7, 8 Laiacona et al., 1998	Biological categories (animals, fruit and vegetables, not separately analysed) more impaired than artefacts (tools, vehicles, and furniture not separately analysed)	DAT	Seven patients out of 8 were males. Only picture naming was analysed. Concomitant variables were strictly controlled in the statistical comparison carried out separately for each patient
18 cases out of 58 Garrard et al., 1998	Animals more impaired than objects and vehicles, which are not distinguished	DAT	Semantic probes and objects decision were not investigated
Exp. 1[b]: 1 case Gonnerman et al., 1997 Exp. 2: 10 cases	Exp. 1: vehicles, furniture, clothing, and weapons less impaired than than fruit and vegetables. Exp. 2: as above but tools replaced weapons, and animals were added	DAT	The authors claim that 10 patients out of 15 (Experiment 2), and some other cases from Experiment 1 (which included 15 different patients) showed a prevailing impairment of biological categories. The authors suggest that the relative impairment of biological categories is observed among the more severe patients. However, no statistical comparison supports the category effect within each subject
5 cases H. Damasio et al., 1996	Animals only	Not detailed	Anterior sector of left inferior T region. The authors claim that the defect was restricted to lexical retrieval, but this conclusion seems unwarranted (for a thorough comment see Caramazza & Shelton, 1998)

2. Primary artefacts impairment[a]

Cases/Authors	*Disproportionately impaired and spared categories*	*Etiology*	*Comments*
No. 24, 25, 26 Laiacona et al., 1998	Artefacts (tools, vehicles, and furniture not separately analysed) more impaired than biological categories (animals, fruit and vegetables, not separately analysed)	DAT	All three patients were females. Only picture naming was analysed. Concomitant variables were strictly controlled in the statistical comparison carried out separately for each patient.
3 cases out of 58 Garrard et al., 1998	Vehicles and objects more impaired than animals	DAT	Semantic probes and object decision were not investigated
Exp. 1: 1 Case[c] Gonnerman et al., 1997 Exp. 2: 3 cases	Exp. 1: vehicles, furniture, clothing, and weapons more impaired than fruit and vegetables. Exp. 2: as above but tools replaced weapons, and animals were added	DAT	The authors claim that 3 patients out of 15 (Exp. 2), and some other cases from Exp. 1 (which included 15 different patients) showed a prevailing impairment of nonliving categories. They suggest that the relative impairment of artefacts is associated with a mild severity. However, no statistical comparison supports the category effect within each subject
17 cases out of 31 Tippett et al., 1966	Speeded picture naming 14 right T: no deficits 17 left T: impaired, more severely on artefacts than biological categories	T lobectomy for intractable epilepsy	This study concerns the mean of the performances of the left T lobectomy patients. These data are uninformative with respect to semantic knowledge or the structural description system. They are not in line with the role suggested by Damasio for the left T pole
7 cases H. Damasio et al., 1996	Tools only	Not detailed	Posterior sector of left inferior-T and the most anterior part of the lateral O region. The authors claim that the defect was restricted to lexical retrieval, but this conclusion seems unwarranted (for a thorough comment see Caramazza & Shelton, 1998)

[a]Due to their limited or summary study, these patients will not be considered for further classification.
[b]One patient had a clear advantage for artefacts (100% vs. 67%).
[c]One patient had a clear advantage for biological categories (92% vs. 54%).

APPENDIX C

Details about the status of "food" in patients presenting category dissociations

1. Patients with biological categories impairment

Name	*Age, gender*	*Impaired categories*	*Meaning and extension of the label "food"*
FB	19, M	Animals and food.	No details given (a category of plant life is not separately considered).
FELICIA	49, F	Biological items (animals, fruit, vegetables and flowers) food.	Food is listed among NLC, and separately from fruit and vegetables.
ING	44, F	Animals, food.	15 items (Exp. 8; items not reported in Appendix).
JBR	23, M	Biological categories and food.	Food is considered separately from fruit and vegetables (Bunn et al., 1997), but is mixed with fruit and vegetables in Warrington and Shallice's (1984) Exp. 4.
KB	60, F	Animals, food.	5 items only (Exp. 8; items not reported in Appendix).
LA	54, F	Animals possibly more severe than flowers. Fruit and vegetables. Food intermediate (1st exam), more severe at 2nd exam.	Food distinguished from fruit and vegetables.
MD	34, M	Fruit and vegetables (animals and food spared).	Food distinguished from fruit and vegetables.
MU	30, M	Biological categories; liquids, substances, edible materials.	Edible liquids (e.g., olive oil) and solid edible substances (e.g., nutella cream). No separate data for edible/non-edible liquids.
PS	45, M	Animals and vegetables (fruit intermediate, food spared).	Food distinguished from fruit and vegetables.
RS	63, M	Disproportionate impairment of fruit and vegetables and food.	Manufactured food.
SB	19, F	Animals, food (including fruit and vegetables).	Food includes fruit and vegetables in naming (Exp. 1). In Exp. 2. real food naming is distinguished into different subtypes: SB was 1/21 correct for fruit and vegetables, and 3/41 correct for the remainder.
SBY	48, M	Natural categories and food.	Food composition (Exp. 5, stimuli taken from Snodgrass and Vanderwart set) is not detailed.

2. Patients with artefacts impairment

JJ	67, M	Impairment of the categories different from animals, i.e., vegetables, fruit, food, body parts, clothing, furniture.	Food distinguished from fruit and vegetables.
KE	52, M	Taking into account the mean percentage of errors over six tasks, body parts, furniture and clothing were the most impaired, whereas food, vegetables and fruit were the least; water animals, transportation, other animals and birds intermediate.	Food distinguished from fruit and vegetables.
VER	68, F	Objects more impaired than food, flowers, and animals; no further distinction between subtypes of objects.	Food stimuli were photographs cut out of recipe books: part of food consisted of fruit and vegetables, part of prepared dishes (e.g., soup and steak).

APPENDIX D

Status of musical instruments and body parts in patients presenting the opposite types of LC/NLC category dissociation[a]

Case	*Balance between biological categories and artefacts*	*Status of body parts*	*Musical instruments*
BD	Biological categories impairment	Unexplored	Spared
C(CW97)	Animals impairment	Unexplored	Spared (the patient was a musician)
CA	Biological categories impairment	Spared	Intermediate
DM	Animals impairment	Slightly impaired	Severely impaired
EA	Biological categories impairment	Spared	Impaired (animals and musical instruments recovered more than fruit and vegetables)
EW	Animals impairment	Spared	Nearly spared
FELICIA	Biological categories impairment	Spared	Spared
FM	Biological categories impairment	Spared	Impaired
FS	Animals impairment	Unexplored	Impaired (four items only)
GR	Biological categories impairment	Spared	Impaired
HJA	Biological categories impairment	Impaired	Unexplored
JB	Biological categories impairment	Relatively spared	Unexplored
JBR	Biological categories impairment	Spared	Impaired
JH	Biological categories impairment	Spared	Unexplored
JMC	Biological categories impairment	Unexplored	Impaired
KG	Animals impaired	Unexplored	Impaired
LA	Biological categories impairment	Spared	Impaired
LF	Biological categories impairment	Spared	Impaired
LH	Biological categories impairment	Mildly impaired	Intermediate
MB	Biological categories impairment	Spared	Intermediate
MD	Fruit and vegetables (animals spared)	Spared	Unexplored
MF	Biological categories impairment	Spared	Intermediate
MU	Biological categories impairment	Spared	Intermediate
NV	Biological categories impairment	Spared	Impaired
PS	Biological categories impairment	Spared	Unexplored
RC	Biological categories impairment	Spared	Unexplored
SE	Biological categories impairment	Spared	Minimally impaired or spared
CG	Artefacts impairment	Spared	Impaired
CW92	Artefacts impairment	Only two stimuli, both failed	Impaired
GP98	Artefacts impairment	Spared	Moderately impaired
JJ	Categories other than animals	Impaired	Unexplored
KE	Furniture and clothing most impaired	Impaired	Unexplored
PL	Artefacts impairment	Relatively spared	Severely impaired
SM	Artefacts impairment	Impaired	Severely impaired
YOT	Small manipulable objects	Impaired	Impaired

[a]Data generally refer to picture naming or picture identification; different tasks are indicated.

APPENDIX E

Critical comments on the data base

In this appendix we critically review the cases listed in Appendix A, arguing whether or not the claims made by the respective authors are well founded. When the original data analyses were not exhaustive, we have tried to supplement these analyses with our own on the basis of the published data. We have used generalised linear model analyses to study the logistic regression of correct/incorrect responses; the resulting linear model includes several relevant variables. In some instances we could study reported frequencies with multi-dimensional contingency tables, considering as main factors (1) correct vs. incorrect responses, (2) patients vs. controls, and (3) answers to probes concerning perceptual vs. associative knowledge. This analysis was often only possible for living categories. Such data can be analysed equivalently with either a log-linear or a logit-linear model (Capitani & Laiacona, 2000). We are aware that this approach offers only approximate answers: collapsing control subjects into a single cell does not take into account variation within normals, thus treating them as a whole. In this situation it is possible that a single patient's performance could still be within the central 95% of the controls' distribution, while at the same time being significantly different from the collapsed controls. Notwithstanding this caveat, we will consider significant findings as a suggestive piece of evidence.

1. Cases presenting a disproportionate impairment for natural categories

BD (Hanley, Young, & Pearson, 1989)
This case was studied primarily for his difficulties in identifying people. He was impaired at identifying pictures of fruit, flowers, and vegetables. The patient was also impaired in naming animals and fruit from spoken definition. The concomitant nuisance variables were not strictly controlled. Musical instruments were not noticeably impaired. Perceptual and associative knowledge were not investigated. Object reality decision was within normal limits.

C(CW97) (Wilson, Baddeley, & Kapur, 1995; Wilson, 1997)
This case is reported with different initials in two studies (C and CW). The patient presented a semantic deficit for animals but was not examined for other biological categories. Musical instruments were substantially spared on different tasks (picture naming and picture recognition); it should be noted that the patient was a professional musician. Perceptual and associative knowledge were not investigated.

CA (Capitani, Laiacona, & Barbarotto, 1993)
Separate data for perceptual and associative probes were not reported in the original paper. However, for perceptual knowledge, CA was 45% correct (27/60) for biological categories and 78% correct (47/60) for artefacts. For associative knowledge, CA was 53% correct (32/60) for biological categories, and 68% correct (41/60) for artefacts. The interaction between type of knowledge and category was not significant after adjusting for the level of difficulty of the questions. This case, affected by a progressive cerebral atrophy, was only examined with CT-scan. Left sylvian atrophy was evident, but we are not sure that the atrophy was confined to the lateral aspects of the left hemisphere, as details of inferior and mesial temporal structures are not evident on axial CT-scan slices.

DANTE (Sartori, Job, & Coltheart, 1993a)
This patient had a disproportionate impairment for naming pictures of biological items; the impairment disappeared after phonological cue. Biological categories were not further distinguished. Semantic knowledge of perceptual properties was assessed by means of a sentence verification task, and Dante performed within the normal range for both animals and objects. Perceptual knowledge was also investigated with visual tasks. Associative knowledge was not investigated. The authors claim that the naming impairment for biological stimuli was purely lexical, due to retrieval difficulties from the phonological output lexicon. This conclusion does not seem entirely warranted: Successful naming improvement after phonemic cue may also reflect the disambiguation of uncertain identification of the stimulus within a group of semantically similar alternatives.

The patient scored within the normal range for both biological stimuli and artefacts on object reality decision. However, on visual part–whole matching, only investigated for animals, performance was not normal (13/16 correct, which corresponds to a z-score of -3.14 with respect to the control group, which was nearly at ceiling). This seems to be at odds with the conclusion of a purely anomic deficit.

DB (Lambon Ralph, Howard, Nightingale, & Ellis, 1998)
This patient, examined on several different picture naming tasks, presented a consistent advantage for artefacts that was more significant for low-familiarity items. Subsets of biological stimuli were not distinguished.

Semantic knowledge was examined with three tasks. Using well-controlled materials, neither a difference due to type of question, nor an interaction between category and stimulus type was detected. Performance on object reality decision tasks, examined with BORB as well as another battery, indicated a deficit for animals.

DM94 (Breedin, Saffran, & Coslett, 1994b)
This report focuses on a reversed concreteness effect. Category effects were observed with a task in which the patient had to pick the odd one out of a triplet of names. The patient was at chance with animals and musical instruments; on a restricted subset of matched stimuli DM was worse with animals than with tools.

The patient was also examined on semantic probes, but the data is not completely reported. For the semantic probes, a category effect was no longer evident (biological categories were slightly better, although not significantly), and on a subset of the questions DM was better with associative than perceptual attributes. However, the results are not divided into all combinations of semantic categories and knowledge types. Object reality decision was below normal range, but a controlled comparison between animals and other stimuli was not carried out.

Due to the inconsistency of the category effects and the limits of the experimental design, this case provides no information as to the relationship between semantic categories and perceptual and associative knowledge.

DM97 (Humphreys, Riddoch, & Price, 1997)
This patient was disproportionately impaired for naming biological items: 46% correct (35/76) for biological items, vs. 75% (57/76) for artefacts. The patient was also examined on naming from definitions based on perceptual or functional information: the patient performed poorly on perceptual definitions, both for animate stimuli 34% (13/38) and artefacts 50% (19/38). For the same perceptual definitions, controls were 81% correct (31/38) for animate stimuli and 66% correct (25/38) for artefacts. The data for naming from functional definitions are not reported separately for each object category: 89% (68/76) for DM(97) and 93% (71/76) for controls. A reanalysis of this patient's data is not possible because the number of controls is not indicated. By inspection, however, the difference between DM(97) and the controls' average is clear for animate stimuli (34% vs. 81%) but is much smaller for artefacts (50% vs. 66%). We should point out that the controls' performance reported in this paper is different from the controls' data reported in Forde et al. (1997: patient SRB) in which the patient was presumably administered the same test.

Object reality decision was impaired; however, the materials used do not permit a comparison between categories.

EA (Barbarotto, Capitani, & Laiacona, 1996; Laiacona, Capitani, & Barbarotto, 1997)
This patient presented a clear semantic deficit for biological categories, with no difference between perceptual and associative information as examined with verbal semantic probes. The deficit was detected on three successive examinations separated by long time intervals. At the outset, EA also presented an impairment for musical instruments, while body parts were nearly spared. On an object reality decision task, EA was slightly impaired for biological categories on the first administration (80% correct, normal ≥87%), but was 100% correct at the second administration.

A re-examination of the patient 9 years later (unpublished data) revealed that the patient was still impaired for biological categories, although picture naming was also still defective for artefacts. On this re-examination, the patient had a greater impairment for fruit and vegetables on word–picture matching as well as on a verbal questionnaire. A slight discrepancy between animals and plant life was evident at the first assessment, and animals recovered to a greater extent. On the last assessment, animal stimuli were 100% correct on word–picture matching, compared to 60% for plant life. On semantic probes, EA was 75% correct with animals, and 52% correct with plant life. The recovery of musical instruments was similar to that of animals. Also on the re-examination, the integrity of the structural description system was further confirmed by the normal performance of EA on an object decision test carried out with new and strictly controlled materials.

EC (Carbonnel, Charnallet, David, & Pellat, 1997)
This patient is reported to have an impairment for perceptual knowledge across object categories; however, the impairment for associative knowledge was limited to animals. In addition, EC was impaired for all categories on a number of pre-semantic visual tests.

The study of perceptual and associative knowledge was limited to the analysis of the correct elements given by the patient in a word definition task, thus providing only weak evidence. If supported by stronger data, a possible interpretation of this pattern could be an association between visual agnosia and a semantic deficit limited to animals.

ELM (Arguin, Bub, & Dudek, 1996; Dixon, Bub, & Arguin, 1997; Dixon & Arguin, 1999; Dixon, 1999; Takarae & Levin, 2001)
The authors label the patient as having a category-specific visual agnosia, and the investigations focused on fine-grained analyses of basic visual processes. On picture naming ELM was 39% correct for stimuli belonging to biological categories, and 88% correct for artefact stimuli. However, ELM was also impaired on a sentence verification task tapping visual semantic properties of animals (55% correct, chance = 50%); on questions tapping associative knowledge, the patient was 85% correct, which is slightly below normal range. However, neither the number of stimuli nor control data are provided for the sentence verification task, and we are not sure if the difficulty of the task is comparable for perceptual and associative questions. Semantic properties of artefacts were not explored.

The lack of a controlled and exhaustive comparison between perceptual and associative knowledge pertaining to different object categories makes it problematic to interpret the pattern of semantic knowledge impairment. A deficit on an object reality decision task is reported for animals (59% correct) but not for artefacts (93% correct); however, the number of stimuli is again not reported, and control data are not provided.

The merits of this study are its concentration on fine-grained aspects of the deficit for visual perception of biological stimuli. On the whole, an agnosic component to the category-specific deficit is probable, but a degree of a semantic deficit for the same categories cannot be excluded. In this case impaired object reality decision for biological categories is associated with the possible loss of stored visual-perceptual knowledge for the same categories: this is reminiscent of cases Michelangelo and Giulietta.

The original data have recently been reanalysed by Takarae and Levin (2001) with an extended set of form-related variables, and the category dissociation was confirmed.

EMMA (Gentileschi, Sperber, & Spinnler,2001)
This patient presented a deficit for knowledge pertaining to people, not limited to prosopagnosia, but also involving the retrieval

of relevant biographical knowledge from a given name. As a marginal finding, the authors report a disproportionate impairment for semantic information concerning biological categories, with a balanced deficit for perceptual and associative knowledge. This category-specific effect was assessed with only a semantic memory questionnaire. On a visual object reality decision, the patient scored below normal range, but the materials employed for this task (BORB) do not permit a reliable comparison between categories.

EW (Caramazza & Shelton, 1998)
This case presented a semantic deficit restricted to animals, with sparing of fruit and vegetables as well as other categories, including body parts and musical instruments. EW's category-specific deficit for animals was not modality-specific (for visual knowledge). In various attribute-processing tasks she consistently performed equally poorly for visual and functional/associative statements for animals and, in contrast, within normal limits for all attributes pertaining to inanimate objects. Object reality decision was impaired for only animals.

FA (Barbarotto, Capitani, & Laiacona, 1996)
The published report indicates a picture naming deficit for items from biological categories. On a revisitation of the clinical record, we found that the same pattern was evident in word–picture matching, which suggests that FA's impairment was probably located at the semantic level. Further tasks could not be given because the patient was uncooperative. Therefore, more detailed information about the pattern of semantic knowledge impairment is not available.

FB (Sirigu, Duhamel, & Poncet, 1991)
This patient probably had a greater naming impairment for animals and food than for artefacts. The study focused on fine-grained aspects of tools knowledge. Animals and food were severely impaired on naming, but on matching to sample animals were better than food; however, it is possible that the materials were not matched for the relevant nuisance variables. Perceptual and associative knowledge of animals and food was impaired in a classification task (e.g., "does it live in France?"). The patient was also examined on a naming to description task that contrasted perceptual and functional descriptions, but apparently the experimental design did not include biological category items. Drawing of biological category items was impaired.

FELICIA (De Renzi & Lucchelli, 1994)
This patient presented a reliable categorical dissociation in naming, for which biological categories were disproportionately impaired. By inspection, it would seem that animals were more severely affected than fruit and vegetables; however, the conclusion of a finer-grained dissociation between biological categories is not warranted, as the difficulty of the materials has not been controlled, and because flower naming was even more impaired than animal naming. The patient was also impaired at naming food as well as professions: The interpretation of the latter deficit is not clear, as this category seems to not be comparable with concrete items (i.e., biological categories or artefacts). Interestingly, neither musical instruments nor body parts were considerably impaired.

This study presents some problems. Stimuli belonging to different categories were not matched for all of the relevant concomitant variables. It is not specified whether each item was investigated with both perceptual and associative questions, or whether different stimuli were used for different types of questions. For associative questions, control data are not reported and were not considered in the statistical comparison; also, it could be that the associative questions were easier. We will ignore whether the difference in performance between different types of knowledge is greater for the patient than for controls. For biological categories, some aspects of associative knowledge were also impaired, as in questions such as (1) "does the animal live in Italy?" and (2) the categorisation of animals according to the way they move. The number of perceptual and functional/associative questions is not specified. On the whole, a selective or disproportionate impairment for perceptual knowledge of biological categories is possible, but is not definitively demonstrated; it is evident that some functional/associative information was not available to the patient.

Object reality decision was impaired for only animal stimuli.

Felicia was observed twice, with more than 2 years separating the two assessments. The bulk of reported data is from the second examination. The authors hypothesise that perceptual knowledge was initially impaired for all categories, and that the recovery of perceptual knowledge was limited to artefacts. However, perceptual knowledge of artefacts was not evaluated at the first examination.

FI (Barbarotto, Capitani, & Laiacona, 1996)
This patient presented a disproportionate naming impairment for biological categories. Data concerning the balance between perceptual and associative knowledge of different categories is not available.

FM (Laiacona, Barbarotto, & Capitani, 1993)
A semantic deficit for biological categories was evident in naming, word–picture matching, and semantic probes. Perceptual and associative knowledge of items from biological categories were impaired to comparable levels.

Data for object reality decision was not reported in the original paper. However, data recovered from the clinical record shows that object reality decision was within the normal range for biological categories: 87% correct (26/30); normal range 87% and above, as well as for nonliving categories: 97% (29/30); normal range: 83% and above.

Animals, fruit and vegetables were impaired to an equivalent degree. Musical instruments were impaired on all semantic tasks while body parts were spared.

FS (Dixon, Piskopos, & Schweizer, 2000)
Although the authors classified this case as a category-specific agnosia, only picture naming was evaluated. The integrity of

associative and perceptual knowledge and of the structural description system were not assessed. The evidence in favour of a category-specific impairment is based on the patient's performance on four items from each of the categories artefacts, musical instruments, and animals, although the items were repeated five times. The stimuli were matched for frequency, familiarity, and visual complexity, but apparently were not matched for name agreement, image agreement, and prototypicality. The small number of stimuli from each category does not permit strong general conclusions.

GC (Cardebat, Demonet, Celsis, & Puel, 1997)
The paper describes a case affected by left temporal lobe degeneration, who presented a deficit for semantic knowledge of animals (other biological categories were not tested). The study is focused on SPECT data and does not provide relevant information regarding either the type of knowledge impairment or the sparing/impairment of the structural description system.

GIULIETTA (Sartori, Miozzo, & Job, 1994b; Sartori, Job, Miozzo, Zago, & Marchiori, 1993b)
This patient presented an impairment for naming pictures of biological items; there did not seem to be a substantial difference between animals and plants (30% vs. 41% correct respectively). On semantic probe questions about animals the patient was 93% correct (54/58) for associative questions, and 62.5% correct (50/80) for perceptual questions; the control average for perceptual questions was 86.6% correct (69.3/80); however, associative questions were not administered to controls. The patient made errors on rather easy associative probe questions about animals ("The elephant is typical of Christmas day" and "The leopard lives in our region"). On an object reality decision task, Giulietta was impaired for only animals (she correctly judged all the real elements but rejected nonexistent ones at chance). The evolution of this case is reported by Sartori, Miozzo, and Job (1994b): The patient did not recover after 8 months of cognitive rehabilitation.

A disproportionate impairment for perceptual knowledge of animals is possible, but a strong conclusion cannot be drawn on the basis of the published analysis due to inadequacies in the experimental design: (1) the semantic probes tapping visual and associative knowledge of animals were not administered for the same stimuli; (2) no control data is provided for associative probes; thus, it could be that these probes were easier than the perceptual probes; (3) the task was slightly different for associative and perceptual probes, since in the former the patient was given a list of names and asked to indicate which item was (e.g.) ferocious, whereas the perceptual probe questions were administered one at a time. No direct comparison is made between associative and perceptual knowledge of biological categories.

A reanalysis of the available data might yield further information; however, no control data have been given for associative probes. Let us then consider only natural categories, in order to check whether or not the patient is in fact more impaired on probes tapping visual properties compared to probes tapping associative properties. It is reasonable to presume that, on associative probes of biological stimuli, controls would perform at a level between the score of Giulietta and ceiling (i.e., 100% correct). Let us first assume that the 10 controls were at the level of Giulietta, i.e., 54/58 correct. Their correct answers would be 540/580. For the visual probes, Giulietta was correct on 50/80 probes, and controls were 693/800 correct. Analysing the above frequency by means of a log-linear model, the overall difference between Giulietta and the control group is significant, $\chi^2(1) = 19.118$, $p < .0001$, and the difference between visual and nonvisual probes is significant, $\chi^2(1) = 28.042$, $p < .0001$. The interaction between the above factors is also significant, $\chi^2(1) = 6.168$, $p = .013$. This indicates that Giulietta had a disproportionate deficit for perceptual probes pertaining to natural categories. An even more significant outcome is observed if the performance of controls is assumed to be at ceiling, $\chi^2 = 9.928$, $p = .002$.

One limit to our approach comes from the possibility that the associative probes were so easy that a deficit could not be detected in the patient; however, at the same time, performance on associative probes has often been impaired in similar cases (see, e.g., Felicia, who was defective in judging if an animal lives in Italy). Thus, we think that this case provides some evidence in favour of a disproportionate deficit for the visual knowledge of animals.

GP97 (Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997)
This patient was examined on three tasks: picture naming, word–picture matching, and superordinate comprehension (e.g., pointing to a "gun" as the examiner gives the word "weapon"). The artefact categories examined were furniture, vehicles, weapons, and clothing; the biological categories examined were fruit and vegetables. Items from different categories were matched only for prototypicality. Performance for biological categories was more impaired than performance for artefacts, with this pattern being consistent across all time slices (four examinations). Different aspects of semantic knowledge were not examined.

GR (Laiacona, Barbarotto, & Capitani, 1993)
This patient had a possible sparing of animals compared to fruit and vegetables (in picture–word matching animals were 95% correct while fruit and vegetables were 65% correct; on semantic probes animals were 63% correct while fruit and vegetables were 50% correct). However, a controlled comparison of performance for the different categories was not carried out. Musical instruments were severely impaired in naming (20% correct), but only slightly impaired in word–picture matching (85% correct) as well as on semantic probes (83% correct). Body parts were spared.

For this patient, object reality decision was not reported in the original paper. Data recovered from the clinical record reveal that object reality decision was impaired for living categories (53% correct, 16/30; normal range: 87% and above) but was normal for nonliving categories (93% correct, 28/30; normal range: 83% and above).

HELGA (Mauri, Daum, Sartori, Riesch, & Birbaumer, 1994)
This patient was impaired on naming items from biological categories (animals and vegetables were not distinguished). For the remainder of the study only animals were considered. The items used to investigate perceptual and associative knowledge of animals were probably not the same, and the authors did not directly compare these types of knowledge. For animals, perceptual probes were 24/30 correct while nonperceptual probes were 40/44 correct, $\chi^2(1) = 1.816$, n.s.. No control data is provided for associative questions. The evidence provided by this case is inconclusive with respect to the contrast between associative and perceptual semantic knowledge. Object reality decision and part-whole matching were impaired for animals.

HJA (Riddoch & Humphreys, 1987a; Riddoch, Humphreys, Gannon, Blott, & Jones, 1999)
This case, classified as "integrative visual agnosia," was first reported in 1987 and then re-examined 10 years later. We will comment only on the data concerning the category-specific impairment as well as the performance of the patient on semantic probe questions. Data reported in 1987 show that HJA named fewer "structurally similar" items (animals, birds, insects, fruit and vegetables) than structurally distinct items (body parts, furniture, household items, tools, vehicles). In the Appendix all the stimuli are reported together with their name frequency as well the naming success. The authors claim that only structural similarity can account for the observed outcome, because name frequency had no effect on HJA's naming; they also maintain that the animate/inanimate distinction was not the right explanation because, for instance, "body parts" are animate but are structurally distinct. However, this is problematic because the literature suggests that body parts should not be collapsed with other categories (for a review, see Barbarotto, Capitani, & Laiacona, 2001).

We have reanalysed HJA's naming data excluding body parts stimuli, as well as one unique musical instrument (piano) and one item with no reported word frequency (lettuce). One might claim that the elimination of body parts disrupts the balance between the remaining living and nonliving categories, or between the remaining structurally distinct and structurally similar categories; however, excluding body parts cannot influence whether or not there is an effect of contour overlap on naming success for the remaining stimuli. On the other hand, HJA successfully named only three body parts out of nine, and this militates against the general rule, suggested by the authors, that in this patient distinct categories are the least impaired. In the logistic regression analysis the dependent variable was the response (correct or incorrect) while the model variables were word frequency and category. Frequency did not have an influence on naming, $\chi^2 < 1$; nor did frequency influence performance after logarithmic transformation, $\chi^2(1) = 1.202$, n.s. In contrast, stimulus category did account for the observed outcome, yielding a $\chi^2(1) = 7.860$, $p = .005$, and $\chi^2(1) = 7.623$, $p = .006$ when the frequency effect was partialled out.

At this point the question becomes: What does "category" really mean? The authors claim that the relevant distinction is that between structurally similar and structurally distinct exemplars; however, after eliminating body parts, the dichotomy between biological items and artefacts works just as well. In their subsequent paper (1999) the authors clarify what is meant by structural similarity ("overall contour overlap and listed number of parts in common"); quantitative measures are provided in other papers (Riddoch & Humphreys, 1987a; Humphreys et al., 1988). Therefore, it was possible to compute directly the effect of contour overlap for the majority of the items belonging to biological categories (32/35) and artefacts (22/30) in the 1987 study. In the logistic regression analysis performed on this subset of 54 stimuli, the model included word frequency (logarithmic), category, and contour overlap. Again, in this subset of stimuli, frequency was not influential, $\chi^2 < 1$, whereas category was highly significant, both when considered alone, $\chi^2(1) = 6.664$, $p = .01$, as well as within a model that included all three predictors, $\chi^2(1) = 6.682$, $p = .01$. On the contrary, contour overlap never yielded a significant chi-square (< 1 both when considered alone as well as within the model including all three variables). Furthermore, an examination of the interaction between category and contour overlap revealed that the effect of the latter variable was not different for artefacts and biological categories, $\chi^2(1) = 2.303$, $p = .129$, n.s. It is also interesting to check if contour overlap was influential within only biological items ("structurally similar" categories); thus, we investigated its role separately for natural entities and artefacts. For biological categories, the effect of contour overlap fell far short of significance, $\chi^2 < 1$, whereas for artefacts there was a trend, $\chi^2(1) = 3.023$, $p = .08$. For biological items, the contour overlap of items that were correctly and incorrectly named was almost identical; for artefacts, stimuli that were named correctly tended to have (paradoxically) greater amounts of contour overlap (although this did not reach significance, see above). Summing up, it seems better justified to denote these two groups of stimuli as biological items and artefacts, than to distinguish them on the basis of their structural similarity.

On probe questions, which concerned only biological items, HJA performed well when the stimuli were presented auditorily but poorly with pictorial presentation of the same items, suggesting that semantic knowledge was preserved. Visual knowledge was still unimpaired more than 10 years later on forced-choice tasks ("is A larger than B?").

With respect to the structural description system, HJA performed poorly on an object decision task with line drawings (69/120), but showed a significant improvement with silhouettes (63/88), approaching normal range (65–85). The authors therefore suggest that HJA is impaired in integrating local part information with information about global shape. This pattern of impairment was confirmed in 1997. However, deterioration of drawing from memory was observed and the authors suggest that ongoing reinforcement of the input is important to preserve visual properties in long-term memory. A general decrease in HJA's semantic knowledge was not observed; nevertheless, on definition tasks, the production of visual attributes decreased for structurally similar (biological) items.

The authors interpreted HJA's deficit as a case of integrative visual agnosia (a form of apperceptive agnosia). Data is not provided by category for object decision, so we do not know if there was a category-specific effect in this task. However, if there was a category-specific impairment for picture naming, as well as for drawing from memory, and if stored semantic knowledge was spared at the first examination, then it is possible that HJA originally suffered from a categorical impairment at a pre-semantic stage.

IL (Lecours, Arguin, Bub, Caille, & Fontaine, 1999)
This patient presented a reliable category-specific impairment for biological categories in picture naming. Object reality decision was more impaired for pictures representing animals, fruit and vegetables, compared to pictures of artefacts. Perceptual and associative semantic knowledge were not investigated.

ING (Warrington & Shallice, 1984)
This patient was only examined on word–picture matching. Neither attribute knowledge nor object reality decision were directly examined. Processing difficulty of the materials was not controlled. The impairment for food (85% correct) was intermediate between animals (80% correct) and inanimate objects (97%).

JB (Riddoch & Humphreys, 1987b; Humphreys, Riddoch, & Quinlan, 1988)
This patient was classified by the authors as a case of semantic access agnosia and optic aphasia. JB had a severe naming deficit, but was not impaired on an object reality decision task, suggesting that his stored perceptual knowledge was spared at the pre-semantic level of the structural description system. (However, performance on the "Heads" test, drawing completion, and drawing from memory was impaired.)

The patient was more impaired at naming pictures for stimuli belonging to "structurally similar" compared to "structurally distinct" categories. This distinction largely overlaps with the contrast between, respectively, biological categories and artefacts, with the exception of body parts, which are natural but are also, according to the authors, a structurally distinct category. Based on the patient's good naming performance for body parts, the authors suggest that the natural–artefact contrast cannot account for the pattern of naming impairment. However, many cases have now demonstrated that body parts cannot be collapsed with animals and plant life in the study and discussion of category effects (for a review, see Barbarotto et al., 2001). The authors further suggest that the crucial variable here is the degree of contour overlap, which differentiates biological categories (high overlap) from artefacts (low overlap). However, the degree of contour overlap did not correlate with the naming success within each category, and on this basis the authors have suggested a more complex and general interpretation of the role of this variable in the process of naming.

To disentangle the relevance of the category classification from that of contour overlap, we have reanalysed the data reported in Appendix D (Riddoch & Humphreys, 1987b) eliminating the 10 body parts stimuli and the unique musical instrument (bell). For the four stimuli whose name frequency is not indicated in the paper, we have introduced the value of zero: presumably, their low number should not alter the general outcome of the analysis. In the remaining set of 77 stimuli, the names of items from natural categories were of lower frequency and their contour overlap was higher (16.67) than that of artefacts (10.76). In the logistic regression analysis the dependent variable was the response (correct or incorrect); the model variables were word frequency (logarithmic), contour overlap, and category. Frequency and category were highly significant, both when considered one at a time and within a model including all three predictors: in the latter cases, $\chi^2(1) = 14.984$ for category and 11.257 for frequency effects. On the contrary, contour overlap never yielded a significant chi-square (3.568 when considered alone and 1.606 within the three-variables model). Moreover, the interaction between category and contour overlap was not significant, $\chi^2(1) = 0.003$, n.s., showing that the effect of the latter variable was not different between artefact items and natural category items.

A further relevant point for the interpretation of this case is the status of semantic knowledge; it was examined with probes tapping functional-associative properties of natural categories, using pictorial and spoken-name presentation of the stimulus. The patient performed worse with pictorial presentation and was more impaired with specific than with general questions. Interestingly, specific questions with spoken name presentation were 76% correct, a relatively poor performance considering that the patient responded by choosing among two or a few presented alternatives. This raises the question of whether associative verbal knowledge of animals was spared or impaired, as it would be problematic for the interpretation of this case provided by the authors if associative verbal knowledge was impaired. Unfortunately, no control data is provided, and the authors simply concluded that: "JB's relatively poor performance on the specific questions… in the spoken name version of the cued definition tasks may reflect his general intellectual level." The patient was also given questions regarding stored knowledge of visual attributes, but only colour knowledge was investigated; also, as was the case for functional-associative knowledge, the patient performed worse when the stimuli were presented pictorially compared to presentation of the spoken name. However, performance on spoken name presentation was only 48% correct. The deficit for animals, fruit and vegetables was balanced (about 15% correct). Performance on body parts was relatively spared (80%). Musical instruments were not included.

In conclusion, this is a complex case, but the available data and their reanalysis do not exclude the likelihood of (at least) some degree of general semantic impairment affecting biological categories. The hypothesis that category effects are apparent and should be traced back to a crucial role of contour overlap is supported by neither the data nor our own reanalysis of the data.

JBR (Warrington & Shallice, 1984; Bunn, Tyler, & Moss, 1997; Funnell & De Mornay Davies, 1996; Wilson, 1997)
This patient has been reported in several different papers. In the original study by Warrington and Shallice (1984) the patient was more severely impaired for biological stimuli and foods than for inanimate objects in naming and verbal definition tasks. In Experiment 7, the authors examined the ability of the patient to give a definition to 12 stimulus words from each of 26 different categories. Animals were not significantly worse than was expected on the basis of their lexical frequency; whereas, according to the same criterion, other inanimate categories such as precious stones and diseases, were impaired. As a general pattern, the results of Experiment 7 confirm that the set of 26 categories cannot be considered as a whole: Most artefacts were included among the categories showing better performance, and with the biological categories mostly showing worse performances. However, this experiment does not permit conclusions to be drawn at the level of each of the 26 categories. The expected value for each category was calculated solely on the basis of a categorised frequency effect with a different set of names, and other variables were not considered; moreover, only one control subject was examined, and chi-square significance levels were not adjusted for repeated testing. Anyway, JBR was proficient with body parts, and impaired with musical instruments.

An informative study of semantic knowledge was performed by Funnell and De Mornay Davies (1996) by means of a property verification task. In the same study, the patient performed within the pathology range on object reality decision using BORB stimuli, which include mostly animals. Thus we will ignore whether or not the performance of the patient on object reality decision for artefacts was spared or impaired. With respect to the comparison between perceptual and associative knowledge, the authors intentionally included, within both categories, stimuli that had been named or defined correctly (50% of the items) and named or defined incorrectly (the other 50%). Consequently, the category effect is not discernible in this analysis.

JENNIFER (Samson, Pillon, & De Wilde, 1998)
This patient was impaired for natural categories on a number of different naming tasks. By inspection, performance for animals was more severely impaired than for fruit and vegetables (on average, naming was 22% correct for animals, 51% correct for fruit and vegetables, and 73% correct for artefacts) but the contrast between different natural categories was not significant after covariance for a number of concomitant variables. The results are somewhat inconsistent regarding the status of associative knowledge of natural categories. This type of knowledge was impaired in an attribute verification task, but was spared in a categorisation task (sorting animal names on the basis of the country in which they live). However, the categorisation task was presumably easier; thus, the conclusion that visual and nonvisual attributes of natural categories were not differently impaired seems justified. Object reality decision was examined with the BORB as well as with an original task. Whereas with the BORB the results were "slightly below the published norms", on the other task Jennifer performed "quite well," i.e., within the normal range (she was correct on 65 instances out of 72, i.e., 90%); the authors conclude that she "did not appear to be impaired in retrieving the stored structural description of the objects depicted in pictures".

JH (Swales & Johnson, 1992)
This patient presented a deficit for pictures of animals, fruit and vegetables. After rehabilitation, biological category items improved, but after 6 weeks only performance on fruit and vegetables confirmed the recovery, whereas the patient showed a decline for animals. The contrast between animals and fruit and vegetables was not the aim of this study; the difficulty of the questions was not controlled, and the small number of items from each of these subcategories (five animals and five fruits and vegetables) does not permit a sound conclusion to be drawn on the basis of this result.
Perceptual and associative information were not investigated separately.

JMC (Magnié, Ferreira, Giusiano, & Poncet, 1999)
Although the materials used to study this patient were probably not strictly controlled, the category effect in object recognition seems striking (0% for natural items vs. 60% or more for artefacts). Perceptual and associative knowledge pertaining to the different categories was not examined.

JV (Pietrini, Nertempi, Vaglia, Revello, Pinna, & Ferro-Milone, 1988)
This patient presented a deficit for natural categories (animals and plants) on picture naming, word–picture matching, word definition, and naming from description. Also, the patient was impaired in naming man-made objects. The authors claim that plants were "selectively impaired." The impairment was possibly more severe for this category, but the performance of the patient on animals was also below normal range in many instances; furthermore, stimuli corresponding to the categories of animals and plants were not matched for frequency, familiarity, etc. However, while the impairment definitely affected the semantic system, perceptual and associative information were not tested separately.

KB (Warrington & Shallice, 1984)
This patient was examined on only word–picture matching. Factors affecting the difficulty of processing of the materials were not controlled. An impairment for food (55% correct) was intermediate between an impairment for animals (45% correct) and one for inanimate objects (85%). Neither attribute knowledge nor object reality decision were directly tested.

KG (Wilson, 1997)
This patient presented a slight semantic deficit for animals (other biological categories were not examined). Also, performance on musical instruments was impaired. However, some of the reported data seem inconsistent, and perceptual and associative knowledge were not investigated.

KR (Hart & Gordon, 1992)
The interpretation of this case presents some problems. Property verification for the spared categories and associative knowledge of animals were nearly always 100% correct. The patient was much worse than chance on perceptual property judgement of animals with pictorial stimuli, and was consistent on incorrect responses. When given the choice between a previously given incorrect response and the correct response, she almost always chose the wrong response, as if she had consistently false beliefs or as if, in some way, she had decided to give a meditated wrong response. As the task had only two alternatives, it is not possible to disentangle the two possible interpretations envisaged above.

LA (Silveri & Gainotti, 1988; Gainotti & Silveri, 1996)
This patient was examined twice, with an interval of about 8 years. In the first examination, LA presented a balanced deficit for naming coloured pictures of animals, fruit, and vegetables, while performance for food was intermediate. Semantic knowledge of animals was examined with a naming to definition task: The patient made more errors on perceptually based definitions than on definitions based on associative features. However, in this task the set of animals defined on the basis of perceptual features was not the same as the set defined on the basis of functional/encyclopaedic features.

On the second assessment, considering the full set of stimuli, animals were 10% correct, plant life 37% correct, food 15% correct, musical instruments 20% correct, other artefacts 69% correct, and body parts were 90% correct. Animals were named significantly worse than vegetables; however, if only high frequency items are taken into account, the difference is not significant. Semantic knowledge of animals and objects was examined by means of a new naming to definition task, as well as by a sentence verification task. In the former, perceptual and associative definitions were given for the same stimulus. Animals were still disproportionately impaired on naming after perceptual definition, but this condition was also more difficult for control subjects. A data reanalysis indicates that LA was worse than controls, $\chi^2(1) = 53.187$, $p < .0001$, and that perceptual definitions were more difficult, $\chi^2(1) = 7.962$, $p = .005$, but the interaction between these effects was not significant, $\chi^2(1) = 0.748$, n.s. On the sentence verification task, the patient performed poorly on probes concerning perceptual attributes of animals and vegetables (respectively, 13% and 33% correct, with a chance level of 25%). Probes tapping functional properties of animals and vegetables yielded a higher proportion of correct judgments (56%, 9/16, and 67%, 4/6 respectively). In this task, however, controls were at ceiling and latency data could not be analysed; on this basis, as acknowledged by the authors, one cannot exclude the possibility that the living/perceptual condition was more difficult. A disproportionate impairment for perceptual knowledge of natural items is possible, but cannot be considered to be a definite finding.

Data from picture reality decision are not reported.

LF (Barbarotto, Capitani, & Laiacona, 1996; Laiacona, Capitani, & Barbarotto, 1997)
This patient presented with a clear category-specific naming impairment that mildly affected semantic knowledge of items from biological categories. Animals, fruit and vegetables were impaired at a similar level. On picture naming, musical instruments were the most impaired category while body parts were spared. LF was examined twice and was largely recovered at the time of the second examination. The performance on the semantic probes was impaired but too mild for investigating the balance between perceptual and associative knowledge. Notwithstanding the large lesion, which included the left hippocampus and parahippocampal gyrus, the cognitive deficit of the patient was mild, and he showed a remarkable recovery.

LH (Farah, Hammond, Mehta, & Ratcliff, 1989; Farah, Meyer, & McMullen, 1996; Etcoff, Freeman, & Cave, 1991; Takarae & Levin, 2001)
Farah and her coworkers (1989) conclude that LH presented a selective deficit for perceptual knowledge pertaining to natural categories (this was also the most difficult task for controls). The statistical analysis used to support this claim is questionable. The authors compared the performance of LH with that of 12 controls: They first divided the observed scores of the patient by the standard deviation of the controls, and then compared this ratio with the *t*-distribution. For the visual properties of natural items the control distribution is highly skewed; thus, this does not permit the use of the normal or the *t*-distribution for determining the position of a single subject. With such distributions, only nonparametric techniques can determine whether or not a single subject's score is within the normal range. Even for unidirectional tolerance limits, the size of the normal sample should be at least 60 subjects. A probability point yielded by the t-distribution tables is not informative. Thus, in this case we have no real statistical basis for judging whether or not a single score is within the normal range, nor can we judge whether or not the performance on two tests was significantly different for a single subject. This analysis does not really contribute to the comparison between perceptual and associative knowledge impairments.

However, in their 1989 paper, Farah et al. report the data necessary for a more well-founded comparison of the performance of LH on tasks tapping visual and nonvisual knowledge of items from biological and artefact categories. Let us consider biological category stimuli. If the hypothesis of Farah et al. is correct, the difference between visual and nonvisual knowledge of LH should be significantly greater than that of the control group. The sum of correct responses given by controls for visual and nonvisual questions can be reconstructed as follows. For biological categories, correct visual responses were 80.4% × 95 (number of questions) × 12 (number of controls) = 916; correct nonvisual responses were 88.5% × 93 × 12 = 988.

The above frequencies can be entered into a log-linear or into a logit-linear model and compared to the performance of LH. LH performed correctly on 60/95 for visual responses and 79/93 for nonvisual responses; for controls, performance was 916/1140 correct for visual responses and 988/1116 correct for nonvisual responses. The statistical analysis with a log-linear model yields $\chi^2(1) = 12.310$ for the difference between LH and controls and = 38.417 for the difference between visual and nonvisual questions (both highly significant); and $\chi^2 = 2.229$ for the interaction (p = .135, n.s. This means that the greater difficulty LH had with visual than nonvisual questions was not significantly different from that of the control group.

The severe prosopagnosia of this patient was examined by Etcoff et al. (1991). In this study LH was 51% correct with animals and 75% with some fruit and vegetables, but we do not know if the stimuli were of comparable difficulty. These authors also gave LH an object reality decision task, on which the patient was 49% correct with animals and 85% correct with artefacts. No separate data are given for subgroups of the biological categories, possibly because only animals were examined.

On the naming of Snodgrass and Vanderwart pictures, reported in the 1996 paper, the patient was 63.6% correct for musical instruments and 72.3% correct for body parts (the reported percentages correct for natural categories and artefacts were 52% and 84.1%, respectively).

The original data have recently been reanalysed by Takarae and Levin (2001) with an extended set of form-related variables, and the category dissociation was confirmed.

MB (Farah, Meyer, & Mc Mullen, 1996; Takarae & Levin, 2001)

On picture naming with the Snodgrass and Vanderwart set, performance on items from living categories was 33.4% correct, and 76.7% correct for nonliving categories. The data reported in the 1996 paper allow a separate evaluation of musical instruments (49.8% correct) and body parts (83.3% correct). Perceptual and associative knowledge were not examined.

The original data have recently been reanalysed by Takarae and Levin (2001) with an extended set of form-related variables: the category effect was not confirmed on the covariance analysis.

MC (Teixeira Ferreira, Giusiano, & Poncet, 1997)

Naming was examined for only animals and tools. Perceptual and associative knowledge were examined, but separate data are not reported.

MD (Hart, Berndt, & Caramazza, 1985)

The authors report that when asked judgements about category, size, colour, texture, and shape, the patient gave correct responses for all properties, although the responses were hesitant for fruit and vegetables. However, the probes were not controlled and the data are not explicitly given. On categorisation tasks with pictures, the patient's errors consisted entirely of confusions involving the categories fruit and vegetables. Therefore, the deficit does not seem restricted to a problem in accessing lexical representations.

MD named body parts correctly as well as food products outside the categories of fruit and vegetables.

MF (Barbarotto, Capitani, Spinnler, & Trivelli, 1995)

This patient was affected by a severe progressive semantic deficit for biological categories, and by prosopagnosia. In addition he was severely impaired for his knowledge of architecture, a field that had been the patient's profession and the subject of his university teaching; this last deficit involved both pictorial and encyclopaedic knowledge. For a long time MF was still competent in the forensic and managing aspects of his job. For a great part of the progression of the semantic impairment, artefacts were spared and biological categories were severely impaired. Perceptual and associative knowledge of biological categories were not differently impaired. Data regarding musical instruments and body parts were not reported in the original paper, but were available from the original record. Body parts were 100% correct in the December 1989 examination. At the same time, musical instruments were 30% correct in picture naming, 90% correct in word–picture matching, and 75% correct on a verbal semantic questionnaire. Biological categories were 37% correct in naming, 75% correct in word–picture matching, and 63% correct in the questionnaire, whereas artefacts were 87%, 97%, and 97% correct, respectively. Musical instruments were somewhat intermediate between living and nonliving categories on word–picture matching as well as on the semantic questionnaire, even if for naming the patient was severely impaired. Object reality decision was impaired for natural categories.

MICHELANGELO (Sartori, Job, & Coltheart, 1993a; Sartori, Miozzo, & Job, 1993c; Sartori, Coltheart, Miozzo, & Job, 1994a; Sartori, Miozzo, & Job, 1994b; Sartori & Job, 1988; Mauri, Daum, Sartori, Riesch, & Birbaumer, 1994)

This patient is reported in several papers appearing from 1988 to 1994; not all tasks were administered in each of the different examinations. In the original study, the patient was impaired at naming animals and vegetables to an approximately equivalent degree (in a different examination vegetables seemed less impaired than animals, but the former category was collapsed with food). In the 1993 paper, the authors report a disproportionate impairment on a perceptual attributes decision task for animate stimuli compared to inanimate stimuli; in the 1994 paper a substantial sparing of knowledge of nonvisual properties of animals is reported. It is reasonable to assume that the patient did not improve between the two examinations, given that a long time had elapsed since the occurrence of acute encephalitis. It is also worth noting that the patient did not benefit from cognitive rehabilitation (Sartori et al., 1994b).

A disproportionate impairment for perceptual knowledge of biological categories cannot be considered a definite finding on the basis of the published analyses. On perceptual questions concerning biological categories, Michelangelo scored 60% correct (48/80); controls scored 86.9% (69.5/80). On perceptual questions concerning artefacts Michelangelo scored 88.7% correct (71/80); controls scored 90.7% (72.6/80). On associative questions about biological stimuli Michelangelo scored 87.5% correct (35/40). No control data are given, but, as argued for

Giulietta, it is reasonable to suppose that controls were at least at the same level of the patient.

A reanalysis of the available data might yield an approximated evaluation. Let us consider natural categories, in order to see if there was in fact a disproportionate deficit for visual properties compared to associative properties. It is reasonable to presume that the level of control performance on associative probes of biological stimuli was between that of Michelangelo and ceiling (i.e., 100% correct). Let us first assume that the 10 controls were performing at the level of Michelangelo, who was 35/40 correct. Their collapsed correct answers would be 350/400. On visual probes, Michelangelo was 48/80 correct, and controls were 695/800 correct. Analysing the above data with a log-linear model, the overall difference between Michelangelo and the control group is significant, $\chi^2(1) = 23.140$, but the difference between visual and nonvisual probes is not significant, $\chi^2(1) = 2.270$. The interaction between the above factors is significant, $\chi^2(1) = 0.213$, $p = .004$. That is, Michelangelo's deficit is disproportionately severe for visual probes pertaining to biological categories. An even more significant outcome is observed if the missing values of controls are replaced by ceiling performance, $\chi^2(1) = 11.680$, $p = .0006$.

The results of this analysis would support the reality of a greater impairment for perceptual knowledge of biological categories, but should be viewed with caution. In particular, perceptual and associative knowledge were probably assessed in different periods, and the different types of questions were not based on the same stimuli.

On object reality decision, Michelangelo was impaired for animal stimuli but not for artefacts.

MS (Mehta, Newcombe, & De Haan, 1992; Young, Newcombe, Hellawell, & De Haan, 1989)
This patient (reported by the authors as suffering from severe object agnosia) was examined with RT experiments in which a category membership judgment was made for a given noun; the results indicate a deficit for biological categories. No data are reported in support of the presence of a category-specific agnosia (in the strict sense). In a third experiment, the patient showed a priming effect in a lexical decision task for the category names of words belonging to biological and artefact categories. Perceptual and associative knowledge were not investigated. The purported semantic impairment for natural categories is inferred on the basis of the patient's poorer performance on a fluency task as well as on identification from definitions.

The visual imagery ability of this patient was investigated in a distinct study. The patient was impaired at imaging living items, whereas he performed at control level for nonliving items. He showed a definite deficit for both perceptual and factual information about living material given the item's name ("which two of three items were similar" in terms of some visual or nonvisual property).

Summing up, this case presented a disproportionate deficit for living categories across a wide set of tasks, some of which were purely verbal and involved nonperceptual knowledge. Furthermore, the imagery task for living category items had a verbal input. No data demonstrate that the reported object agnosia is reliably category-specific.

MU (Borgo & Shallice, 2001)
This patient presented a disproportionate semantic deficit for biological categories. This deficit was evident in several naming tasks (different visual confrontation naming tasks as well as naming from description), in matching tasks and on semantic probe questions. Perceptual and functional/associative knowledge were equivalently impaired for biological categories: MU's naming of biological items was much poorer than naming of man-made artefacts from both functional/associative and perceptual descriptions; moreover, on a verbal questionnaire MU presented a comparable deficit for perceptual and functional knowledge attributes. With respect to visual-perceptual tasks, MU was slightly impaired on colour naming and identification. With semantic probes, MU showed sparing of body parts (97%) and an intermediate performance for musical instruments (78%). The patient was impaired on object decision tasks (BORB) as well as with silhouettes and progressive silhouettes in the VOSP test: In this latter task no difference was detected between biological categories and artefacts.

The authors have examined the status of the patient's knowledge of other categories, which have seldom been investigated in semantic memory patients: i.e., liquids, edible substances, and materials; the authors argue for a deep similarity between the latter set and biological categories.

NA (Funnell, 2000)
This patient was affected by a progressive cerebral degeneration: She presented a form of apperceptive visual agnosia which caused, according to the author, a disproportionate picture naming impairment for biological categories. Semantic and lexical knowledge were spared: NA correctly responded to 26/28 questions about biological category items, and to 27/28 for artefacts; her few errors occurred in response to functional questions. NA presented a clear visual perceptual disturbance, but the evidence that the category-specific deficit for naming arose at the perceptual level is only indirect. The pictures representing items from biological categories were more visually complex; however, the naming errors made by the patient were not influenced by the visual complexity of the stimuli: This independence seems to not be in agreement with the diagnosis of apperceptive visual agnosia. According to the author, the patient was sensitive to a number of other perceptual characteristics of the stimuli, (such as "joints" between separable parts, etc.); it would have been interesting to check if the stimuli corresponding to biological categories and artefacts were balanced for all these perceptual aspects.

At the first examination body part naming was 69% correct (9/13) and musical instrument naming was 100% correct (5/5).

NA certainly presented an apperceptive visual disturbance, but its categorical specificity can only be inferred from the moderate category effect in picture naming, where the patient performed worse for biological category items on only one out of three tasks. As such, the claim for a categorical organisation of apperceptive stages of visual processing is not supported by strong evidence.

NR (De Haan, Young, & Newcombe, 1992)
This patient was affected by prosopagnosia and amnesia and was impaired on visuospatial perception tests and on name retrieval. A category effect on naming is marginally reported, but object category effects were not further investigated.

NV (Basso, Capitani, & Laiacona, 1988)
This study has been revisited after taking into account the structure of the semantic memory questionnaire, which was not reported in the original paper. On the basis of this revision, we conclude that the comparison between perceptual and associative knowledge is not reliable, as controls were not examined, and all of the stimuli were not investigated with balanced associative and perceptual questions. In particular, perceptual probes concerned only animal stimuli. Therefore, the conclusion of the authors that the patient's impairment disproportionately affected perceptual knowledge is not warranted, as perceptual knowledge was confounded with animal knowledge. Musical instruments were impaired and body parts were spared.

PR (Teixeira Ferreira, Giusiano, & Poncet, 1997)
Naming was only examined for animals and tools. Perceptual and associative knowledge were examined, but separate data are not reported.

PS (Hillis & Caramazza, 1991)
On a picture naming task, the patient was impaired for animals and vegetables; in contrast, fruit was less impaired (although worse than any artefact category). Food and body parts were spared. This association of impaired categories was confirmed in a follow-up examination.

The patient was administered a word definition task, but responses were not analysed in terms of the perceptual and associative information produced by the patient.

RC (Moss, Tyler, Durrant-Peatfield, & Bunn, 1998; Tyler & Moss, 1997)
This case was first reported in 1997 and more extensively described and commented upon in 1998. As the results reported in each account are not in full agreement, we will refer to the latter study. On naming Snodgrass and Vanderwart pictures RC showed an equivalent impairment for animals, fruit and vegetables (9% correct); artefacts were 50% correct while body parts were relatively spared (92%). Similar percentages were observed using a new set of coloured pictures. The patient was examined on a naming from spoken description task (descriptions were based on either functional or visual properties). There were 15 perceptual definitions and 15 functional descriptions for biological items, and the same for artefacts; however, different stimuli were used for perceptual and functional descriptions. Regardless, there was no difference in the patient's ability to identify targets from descriptions based on either functional or perceptual properties for either category (for biological categories, hits were 0 for both perceptual and associative descriptions; for artefacts, hits were 47% and 53%, respectively). With respect to the null performance on associative definitions of living things, there is good evidence for an equivalent impairment to both visual and functional knowledge of natural categories, notwithstanding the lack of strict controls on the materials. Object reality decision data are not reported.

RM (Pietrini, Nertempi, Vaglia, Revello, Pinna, & Ferro-Milone, 1998)
This patient was examined twice. At the first examination, RM was impaired for biological categories on naming, word–picture matching (plants), and word definitions (animals). An equivalent deficit for animals and plants was observed on three tasks, but on word definitions animals were significantly more impaired. However, this latter finding should be viewed with caution due to the possible influence of nuisance variables, the low significance level, and the inflation of type I error risk due to repeated testing. After 18 months, only naming tasks were impaired for both biological categories. Even at the last examination, a subtle semantic deficit cannot be excluded. The criteria for judging if the word definitions were correct are not given. A comparison between perceptual and associative knowledge is not possible.

SB (Sheridan & Humphreys, 1993)
This patient was equally impaired at naming animals and food, the latter of which included many items from the categories of fruit and vegetables. The patient presented an equivalent impairment for stored visual and nonvisual knowledge of biological categories, assessed with an attribute judgment task. Object reality decision and the "Heads" test were within normal range. SB was impaired on drawing from memory.

SBY (Warrington & Shallice, 1984)
This patient was impaired at naming and identifying animals and food, but relatively spared for artefacts. The patient was not administered a separate examination for perceptual and associative knowledge.

SE (Laws, 1998; Laws, Evans, Hodges, & McCarthy, 1995; Moss, Tyler, & Jennings, 1997)
This case was described with contrasting conclusions by Laws et al. (1995) and by Moss et al. (1997), with a further reply by Laws (1998). Laws et al. claimed that the patient, examined 5 years after acute encephalitis, suffered from a very mild naming deficit for biological categories, but the remainder of the study concentrated only on animals. Although the authors report relatively intact naming performance for both animals and objects on a restricted set of stimuli, for the whole Snodgrass and Vanderwart set SE correctly named only 69% (54/78) of animals, fruit, and vegetables. Body parts were 100% correct and musical instruments were 58% correct. On an object decision task, SE scored within the normal range. In the authors' opinion, SE was affected by a disproportionate or selective impairment for associative knowledge of biological categories.

Moss and her colleagues independently re-examined SE and reported that he was 86% correct with artefacts (body parts were 100% and musical instruments were 90% correct), 63% correct with animals (including also birds and insects), and 60% correct for fruit and vegetables. With respect to type of knowledge impairment, Moss and colleagues came to the opposite conclusion to that of the original report, i.e., that the patient had a selective impairment for the visual properties of biological categories. The arguments of Moss and her colleagues can be found in their original paper. The main impairment was found with distinctive visual properties of biological categories, but this deficit was mild (accuracy of SE was .84, whereas the worst control scored .89). A similar conclusion was suggested by other tasks, i.e., definition generation and priming effects.

In his final reply, Laws (1998) argued that the set of stimuli used by Moss and colleagues in their rebuttal study were not appropriate, and further commented on theoretically relevant points. On the basis of these contrasting findings, however, it seems conservative to not classify SE with respect to the degree of impairment for visual and associative semantic knowledge of natural entities.

SRB (Forde, Francis, Riddoch, Rumiati, & Humphreys, 1997; Humphreys, Riddoch, & Price, 1997)
This patient has been reported in two papers. The patient presented a deficit for natural categories that was more severe for fruit and vegetables (58% correct in picture naming) than for animals (81% correct). This difference was consistent across different tasks. SRB also had reading problems (letter-by-letter reading).

In the main study (Forde et al., 1997) the authors investigated picture naming latencies, analysing whether the contour overlap of the stimuli was a better predictor of the performance than the living/nonliving distinction within a model that also included familiarity, frequency, visual complexity, and prototypicality. They concluded that contour overlap was a better predictor than category classification. However, this analysis is not convincing. The set of stimuli used for this analysis included more animals than fruit and vegetables: The full set reported by Humphreys et al. (1988) included 26 animals and 12 fruit and vegetables. Moreover, within this set, only those stimuli named correctly could be considered, thus (probably) further reducing the number of items from the categories of fruit and vegetables.

Relevant data for assessing the balance between perceptual and associative knowledge are reported in both studies, with a naming to definition task contrasting visual-perceptual definitions and functional-associative definitions. However, a comparison of the data reported by Forde et al. (1997) with that reported by Humphreys et al. (1997) reveals several discrepancies (see Table E1). It can be seen that:

(a) The data for perceptual definitions of biological categories and artefacts are crossed in the two papers.

(b) SRB's correct naming performance for the associative condition is (overall) 73/76 in Forde et al. and 70/76 in Humphreys et al.

(c) Control data are not consistent at several points.

Table E1

	Visual-perceptual definitions		*Functional-associative definitions*	
Reference	*Biological*	*Artefacts*	*Biological*	*Artefacts*
Forde et al. (1997)				
SRB	23/38	16/38	35/38	38/38
Controls	32.25/38	32.50/38	37.00	37.50
Range	(30–34)	(21–38)	(36–38)	(37–38)
Humphreys et al. (1997)				
SRB	16/38	23/38	–	–
Controls	31/38	25/38	–	–
Overall				
SRB	39/76		70/76	
Controls (*SD*)	56/76 (4.0)		71/76 (2.1)	

SRB was marginally impaired on object reality decision (BORB) (27/32 correct vs. a control mean of 29.8/32), but this battery includes an overwhelming majority of living category items. In drawing from memory, drawings of natural category items (animals, fruit and vegetables) were worse than those of man-made objects.

Due to the limits of this experiment, this patient does not appear to be informative for the contrast between perceptual and associative knowledge in category-specific dissociations.

TOB (McCarthy & Warrington, 1988, 1990; Parkin, 1993)
This patient was affected by surface dyslexia and dysgraphia. When asked to define pictures and spoken words, the patient was clearly impaired in defining spoken names of biological things, but not in defining pictorially presented stimuli. On this basis McCarthy and Warrington argue for the existence of distinct modality and category-specific cerebral meaning systems. In a later study (Parkin, 1993) the patient did not present a category effect in picture naming when materials were controlled. The impairment for giving specific definitions to spoken names was confirmed for animals but was not present for vegetable names.

The study of TOB does not contribute information regarding the contrast between perceptual and associative knowledge.

TS (Wilson, 1997)
This patient presented a possible semantic deficit for animals (other biological categories were not examined).

TU (Farah & Wallace, 1992)
According to the authors, TU presented a selective naming deficit for fruit and vegetables, with spared semantic knowledge of the same categories. The selectivity of the impairment to fruit and vegetables was inferred from an investigation of naming latencies: In a linear regression model, the classification "fruit and vegetables vs. all other categories" resulted in the most significant factor; however, it was included in the model together with the classification "living vs. nonliving." This statistical

design is not optimal; it would have been preferable to include the living vs. nonliving classification and the contrast (fruit + vegetables) vs. animals (excluding nonliving stimuli from the latter analysis). Table 1 of the paper suggests that animals were probably intermediate between fruit/vegetables and artefacts (Furthermore, the use of logistic regression does not seem appropriate, and other linear models are better suited for an analysis of naming latencies.)

Regarding semantic knowledge, the authors report that "TU had adequate knowledge about fruits and vegetables," but the analysis of the semantic knowledge is rudimentary and details are not given.

The authors claim that the patient was impaired at the lexical level, because phonemic cueing influenced naming success. However, the influence of a phonemic cue may also arise from the disambiguation of poor identification of the stimulus within a group of semantically similar alternatives.

VG (Teixeira Ferreira, Giusiano, & Poncet, 1997)
Naming was only examined for animals and tools. Perceptual and associative knowledge were examined, but separate data are not reported.

MR.W (Rumiati, Humphreys, Riddoch, & Bateman, 1994; Rumiati & Humphreys, 1997; Farah, 1997)
According to the authors, MrW presented with object agnosia without alexia or prosopoagnosia (a claim that has been criticised by Farah, 1997, and further maintained by Rumiati & Humphreys, 1997). The patient was impaired on a "heads and tail" test, but object decision was within the normal range. On a subset of the materials, the patient had a prevailing naming deficit for structurally similar categories, but this was not confirmed on the whole set of stimuli when data were submitted to simultaneous regression analyses with name agreement and other concomitant variables included in the model. The patient probably has a semantic impairment, but the authors do not specify how semantic knowledge of nonliving categories has been examined. The reported data is not exhaustive and is not detailed with respect to individual categories.

2. Cases presenting a disproportionate impairment for artefacts

CG (Silveri, Gainotti, Perani, Cappelletti, Carbone, & Fazio, 1997; Silveri, Perri, & Cappa, 2000)
The authors claim that this patient was affected by a progressive picture naming impairment, with disproportionate severity for artefacts. In their opinion, this deficit was purely lexical in nature; however, a word of caution is suggested as a subtle semantic deficit may have escaped detection. In fact, close scrutiny and reanalysis of the data suggest that the conclusion of a category-specific lexical impairment may not be warranted. The authors administered three different naming tasks; for all three tasks, the category discrepancy appeared only as the disease progressed. On a reanalysis of the contingency tables reported in the first assessment, the category effect was never significant, $\chi^2(1) =$ 1.184 for test 1; 1.002 for test 2; and 2.464 for test 3. Presumably at the same time, word–picture matching and a semantic verbal questionnaire were at ceiling, but these tests were not repeated on subsequent examinations when a category effect was evident. (Even at subsequent examinations, a clear-cut category effect was evident only with naming test 3, whereas differences were marginal or not significant with tests 1 and 2.) Therefore, it is possible that a semantic deficit was present at the later examinations. Interestingly, and consistent with this last possibility, verbal comprehension was impaired on later examinations of this patient (Silveri, Perri, & Cappa, 2000); this suggests a diagnosis of semantic dementia. At first assessment we can presume that the structural description system was spared, as the patient's performance on a word–picture matching task was flawless. Different artefact categories were not explicitly contrasted. Available data indicate that naming of musical instruments was 60% correct, a level closer to that of artefacts (56.7%) than biological items (70%). Performance on body parts was flawless.

CN94 (Breedin, Martin, & Saffran, 1994a)
This patient was given an oddity task on triplets of names (pick the odd one out). Several categories were considered, but only animals and tool stimuli were of comparable mean frequency. The statistical comparison is not clear: a contingency table analysis might indicate more errors on tool stimuli than on animal stimuli. However, it is not clear that the difficulty of the task was balanced across categories, as control performance was at ceiling for both categories. On this basis the evidence in favour of a dissociation is insufficient. Furthermore, the type of knowledge tapped by the triplets is not specified, and could differ between different categories.

CN98 (Gaillard, Auzou, Miret, Ozsancak, & Hannequin, 1998)
The patient presented a relative deficit for artefacts over three assessments on a naming task. The comparison between perceptual and associative knowledge was made with only tools and fruit/vegetables. We have reanalysed the reported data by means of a Fisher exact test: Perceptual and associative information were not differentially affected for biological categories, nor for tools, and the same outcome was observed collapsing these categories together. However, no controls were examined. Given the small number of probes included in this experiment, the statistical comparison between perceptual and functional/associative knowledge would have had sufficient power only if underlying differences were of considerable size.

CW92 (Sacchett & Humphreys, 1992)
The patient was administered picture naming tests, as well as word–picture and picture-word matching. In only one of the picture naming tasks were the stimuli corresponding to artefacts and animals matched for frequency; here, an advantage for animals was evident. (Within the set of artefacts the authors also included five musical instruments and two body parts: However, even eliminating the latter stimuli, the category effect would probably be preserved.) Animal naming was 19/20 correct,

artefacts 6/13 correct, musical instruments 1/5 correct, and body parts were 0/2 correct. In this experiment perceptual and associative knowledge was not distinguished, and an object decision task was not administered. The data are not relevant for a direct verification of any hypothesis about the origin of the category effect. Concerning a possible fragmentation within artefacts, the small number of stimuli used in picture naming for each category prevents a finer grained analysis (the highest number of stimuli was five for clothing and musical instruments, and the smallest was one for vehicles; the number of body parts stimuli was two). For the other tests detailed data are not reported.

DRS (Warrington & Mc Carthy, 1994)
This patient was impaired in the identification of common objects (no other categories were considered in the first part of the study). The authors conclude that DRS presented a category-specific visual associative agnosia affecting artefacts ("... the locus of the deficit appears to lie within those components...that assign meaning to a structured percept, or in access to them"). A study of category-specific effects was then carried out with visual-visual matching of drawings (common objects vs. animals or vehicles) and word–picture matching (common objects vs. animals and flowers or vs. animals and vehicles). According to the authors, the recognition of common objects was disproportionately impaired. However, no control data are given, and stimuli from different categories were not clearly matched for the relevant concomitant variables. The structural description system is reported to be spared on the basis of an object reality decision task (although this conclusion is based on the performance of the patient on VOSP silhouettes, and it is not granted that the patient would have been normal with full-detail drawings). Perceptual and associative knowledge were not tested verbally. The fact that nuisance variables were not controlled makes it problematic to accept the conclusion that artefacts were disproportionately impaired.

ES (Moss & Tyler, 1997, 2000)
This patient, affected by a progressive degenerative disease, was examined from 1994 to 1996. The authors report that she was more impaired for artefacts, and that the category effect became more evident as the disease progressed. They claim that there was a crossover of the category effect in naming from the first to the last examination (with a greater impairment for biological categories at the outset, and for artefacts at the later stage). The initial impairment for biological categories was evident with the whole set of Snodgrass and Vanderwart pictures, but not with a subset in which the stimuli were matched for familiarity (Moss & Tyler, 1997). A reanalysis of the published data concerning the property verification task (Moss & Tyler, 2000) does not confirm a significant advantage for artefacts at the early stage of testing. Visual and associative properties were not differently affected with respect to the stimulus category.

The authors discuss the distinction between shared and distinctive properties for biological and artefact items. We reanalysed the data of the last assessment published in Moss and Tyler (2000) with a logit-linear model that included as factors category type, the shared/distinctive classification, and the type of knowledge (visual or associative) investigated. Here, only the factor of stimulus category significantly influenced the probability of success, whereas neither property type (shared vs. distinctive) nor the visual/associative classification were significant. None of the first order interactions were significant.

No data were given concerning the structural description system.

GP98 (Cappa, Frugoni, Pasquali, Perani, & Zorat, 1998)
This patient presented a disproportionate naming impairment for artefacts, even when musical instruments and body parts were not considered. At the same time, the performance of the patient on a word–picture matching task and on a semantic questionnaire were, respectively, normal and mildly impaired. The stimuli used in the naming task were probably not matched for all of the relevant concomitant variables: The authors divided the items into low and high familiarity groups, and the category effect was confirmed in both subsets. However, this does not rule out the possibility that in both subsets nonliving stimuli were less familiar, or that living and nonliving stimuli were not balanced for other lexical or pictorial variables. Moreover, with respect to the stimuli considered in the main analysis, it would seem that the latter analysis has been carried out on different sets of artefacts (n = 111 vs. 64) and biological items (n = 69 vs. 94). The interpretation that the categorical deficit was confined to the lexical level does not seem entirely warranted for two reasons: First, the patient's performance on the semantic questionnaire was mildly impaired despite the fact that it was very easy (the three controls scored 100% correct, and the format of the test was a fixed-choice task with only two alternatives). As the authors acknowledge, the possibility of a subtle semantic impairment cannot be ruled out. Second, in a word–picture verification test, the patient made 9 errors out of 88 trials (10.2%): all of the errors except 1 were on stimuli that the patient also failed to name.

The impairment for artefacts does not seem homogeneous, as vehicles were relatively spared with respect to tools and furniture. Naming of musical instruments was just moderately impaired.

IW (Lambon Ralph, Howard, Nightingale, & Ellis, 1998)
This patient presented a greater impairment for artefacts than for biological items on several different naming tasks, although the effect was not impressive (raw data were 33% vs. 42% correct); the effect became significant only after covariance for familiarity and other psycholinguistic factors. Interestingly, this patient presented a relative loss of perceptual over associative knowledge for all categories, and her structural description system, examined with a number of different tests, was preserved. This case militates against the necessity of explaining the deficit for biological categories in terms of a loss of perceptual knowledge.

The reported data do not provide details useful to distinguish within animate categories and within artefacts.

JJ (Hillis & Caramazza, 1991)
This patient presented a substantial advantage for animals on oral and written naming and auditory word–picture verification. All other categories examined were severely impaired, the only exception being the category of transportation, which was intermediate. A word definition task was administered at a later stage, but the results were not subjected to a quantitative evaluation in order to investigate different components of semantic knowledge. The structural description system was not investigated.

KE (Hillis, Rapp, Romani, & Caramazza, 1990)
This patient was examined with a set of six tasks tapping comprehension and production of words belonging to 10 semantic categories; the rank of errors observed in each category was consistent across different tasks. Averaging across the six tasks, body parts, furniture, and clothing were the most impaired categories, while fruit, vegetables, and food were the least impaired. However, items were not matched for the relevant concomitant variables. On a sorting task, superordinate knowledge was preserved, as were some aspects of perceptual knowledge of animals (size and colour). Neither different types of knowledge, nor the integrity of the structural description system, were assessed.

M.LUCIEN (Hécaen & De Ajuriaguerra, 1956)
This patient was probably affected by visual agnosia, the type of which is not well defined. The examination focused on visual naming; artefacts seemed more impaired than animals. However, the results were not given a quantitative evaluation, and the other crucial cognitive aspects were not examined.

NB (Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997)
This patient was examined with three tasks: picture naming, word–picture matching, and superordinate comprehension (e.g., pointing to a gun when the examiner gave the word weapon). The artefact categories examined were furniture, vehicles, weapons, and clothing; biological categories included only fruit and vegetables. No distinction was made within either artefacts or biological stimuli. The items from different categories were matched for only prototypicality. The patient was examined four times in 4 years: In the first assessment no discrepancy was evident, but starting from the second examination the patient showed a greater impairment for artefacts (most evident at the third examination and less evident at the final one). Different aspects of semantic knowledge were not examined.

PJ (Breedin, Martin, & Saffran, 1994a)
This patient was given an oddity task on triplets of names (pick the odd one out). Several categories were considered, but only animals and tool stimuli were of comparable mean frequency. The statistical comparison is not clear: A contingency table analysis might indicate more errors on tool stimuli than on animal stimuli. However, it is not clear that the difficulty of the task was balanced across categories, as control performance was at ceiling for both categories. On this basis the evidence in favour of a dissociation is insufficient. Furthermore, the type of knowledge tapped by the triplets is not specified, and could be discrepant between different categories.

PL (Laiacona & Capitani, 2001)
This patient presented a disproportionate impairment for artefacts in naming and word–picture matching, as well as on a verbal semantic questionnaire. In the statistical analyses the comparisons were carried out taking into account a wide set of nuisance variables and some difficulty indices. The authors found neither differences between perceptual and associative knowledge, nor an interaction between knowledge type and category. The patient performed within normal range on an object decision task for all categories. In a follow-up examination, the pattern of category impairment was confirmed, notwithstanding the worsening of the overall cognitive level. No statistical comparison was attempted within the domains of biological categories and artefacts. However, some evidence points toward a possible fractionation of artefacts categories. At picture naming (first examination) biological categories were 37% correct, artefacts 13% correct, body parts 60% correct, and musical instruments 20% correct. Data from the other tasks and follow-up data suggest that, on the whole, body parts were the most preserved category, and musical instrument the least preserved.

SM (Turnbull & Laws, 2000)
The evidence in favour of a disproportionate naming impairment for artefacts is not strong for this case. A category effect was present only among low familiarity stimuli, and a main effect of category was significant for neither high- nor middle-familiarity stimuli, nor for the overall set. Moreover, the naming errors of this patient mirror the performance of controls, as even the latter group presented a disproportionate difficulty with low familiarity artefacts. (The controls' performance, entered alone as a model variable in a data reanalysis with logistic regression, explains 84% of the variability.)

Regarding the verbal semantic probes used to investigate visual and associative knowledge, visual knowledge was slightly more impaired than associative knowledge, but no category dissociation was evident. Concerning object reality decision, SM performed poorly on the VOSP battery; on the BORB battery, SM scored below normal range, but the category effect could not be evaluated due to the low number of artefacts included.

On naming the Snodgrass and Vanderwart picture set, body parts were 42% correct (5/12), and musical instruments were 13% correct (1/8, i.e., the worst performance).

VER (Warrington & McCarthy, 1983)
This patient presented a global aphasia with sparing of object recognition as judged by performance on a picture-object matching task. The category-specificity of her deficit was investigated by comparing spoken word–picture matching of objects and food (Exp. 10) as well as objects, animals, and flowers (Exp. 11). Subtypes of objects were not investigated separately. In both experiments, objects fared worse. The type of semantic knowledge that was spared/impaired was not investigated.

VP (Breedin, Martin, & Saffran, 1994a)
This patient was administered an oddity task on triplets of names (pick the odd one out). Several categories were considered, but only animal and tool stimuli were equated for mean frequency. The statistical comparison is not clear: A contingency table analysis might indicate that more errors were made on tools than on animals. However, the difficulty of the task may not have been equated across categories, as the performance of controls was at ceiling for both categories. On this basis the evidence in favour of a dissociation is insufficient. Also, subtypes of biological and artefact categories cannot be reliably compared. The type of knowledge tapped by the triplets is not specified, and could differ between different categories.

YOT (Warrington & McCarthy, 1987)
This patient presented a global aphasia and phonological dyslexia with impaired comprehension of visual stimuli as judged from a visual–visual matching task. The category-specificity of her deficit was investigated by comparing spoken word–picture matching and spoken word–written word matching. In the former task, indoor objects fared worse than food, flowers, and animals, and in a further analysis small manipulable objects were more impaired than food and large outdoor man-made objects. In tasks of the second type (spoken word written word matching), the most preserved categories were animals, occupations, vegetables, and fabrics, whereas the most severely impaired categories were body parts and furniture. The type of semantic knowledge that was spared/impaired was not investigated. Evidence in favour of a fractionation within the category of artefacts is provided by the spoken word–picture matching task, in which indoor objects were 58% correct compared to 78% for outdoor objects. The former subset mainly included tools, implements and kitchen utensils, whereas the latter mainly included vehicles and buildings. Chance performance in this task is indicated as 20%. In a further spoken word–picture matching experiment, it was found that musical instruments were impaired (33% correct). However, stimuli were not controlled for the relevant concomitant variables.

APPENDIX F

Picture naming severity for those patients presenting a disproportionate semantic impairment for biological categories and for which perceptual and functional/associative knowledge could be reliably compared

1. Perceptual attributes worse than associative attributes only for biological categories: Structural description impaired only for biological categories

Case	*Biological categories*	*Artefacts*	*Δ*	*Mean*
GIULIETTA	56.25%	87.50%	31.25	71.87%
MICHELANGELO	32.90%	74.90%	42.00	53.90%
Mean	44.57%	81.20%	36.63	62.88%

2. Balanced deficit for perceptual and functional/associative attributes of biological categories: Structural description spared

Case	*Biological categories*	*Artefacts*	*Δ*	*Mean*
EA (2nd exam)	3.00%	43.00%	40.00	23.00%
FM	20.00%	70.00%	50.00	45.00%
JENNIFER	36.1%	77.80%	41.70	56.95%
SB	9.50%	35.00%	25.50	22.25%
Mean	17.15%	56.45%	39.30	36.80%

3. Balanced deficit for perceptual and functional/associative attributes of biological categories: Structural description impaired for biological categories

Case	*Biological categories*	*Artefacts*	*Δ*	*Mean*
CA	3.30%	20.00%	16.07	11.65%
DB	58.00%	81.00%	23.00	69.50%
EA (1st exam)	0.00%	17.00%	17.00	8.50%
EW[a]	34.00%	90.40%	56.40	62.20%
GR	13.00%	73.00%	60.00	43.00%
JBR[b]	26.00%	58.00%	32.00	42.00%
MF	37.00%	87.00%	50.00	62.00%
MU	33.30%	75.00%	41.70	54.15%
Mean	25.57%	62.67%	37.10	44.12%

[a]For case EW the reported figures refer to animals vs. tools, furniture, and vehicles.
[b]The reported data for case JBR are drawn from Bunn, Tyler, and Moss (1997).