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When panthers are really pink and diamonds are black. Living things and "mass" kinds knowledge in Herpes Simplex Virus Encephalitis: New evidence for a theoretical redefinition of category specific effects

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To Nicola

"The time has come," the Walrus said,

"To talk of many things:

Of shoes –and ships –and sealing wax –

Of cabbages – and kings—

And why the sea is boiling hot –

And whether pigs have wings."

Lewis Carroll, "The Walrus and the Carpenter"

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Chapter 1

1.1 General introduction

The internal structure and content of the semantic memory system have received considerable attention in neuropsychological studies of patients showing semantic deficits. Within the semantic memory field, an overwhelming number of studies of brain damaged patients has been proposed in the literature which were focused on deficits selectively affecting the knowledge of concrete concepts belonging to either one of two distinct conceptual domains, living things and man-made artefacts, although impairments restricted to the output side have been also described. These so called category-specific deficits have generally been reported to affect both the semantic comprehension and linguistic production of concepts associated to living things or man-made artefacts. The first reports of a double dissociation between the knowledge associated to either one of these two semantic categories are attributed to the seminal works of Warrington and Shallice (1984), who described a group of patients with a selective impairment of living things knowledge relative to man-made artefacts, and Warrington and McCarthy (1983; 1987), where the reverse pattern of deficits and preservations was observed, highlighting the sparing of information related to man-made artefacts as opposed to that of living things. The selective disruption of semantic knowledge associated to the living things domain was the most frequently described in subsequent studies of category specificity. However, an increasing number of single case studies has been reported in recent times showing a selective advantage for living things over man-made artefacts (Sacchett and Humphreys, 1992; Moss and Tyler, 1997; Moss, Tyler and Devlin, 1999; Hillis and Caramazza, 1991; Lambon-Ralph et al., 1998).

Chapter 1

General introduction

The massive disturbance of the knowledge associated to the living things category, in contrast with a normal or almost unimpaired knowledge of concepts pertaining the man-made artefacts class, is the most frequently observed pattern (De Renzi and Lucchelli, 1994; Farah, McMullen and Meyer, 1991; Hart and Gordon, 1992; Moss, Tyler and Jennings, 1997; Sartori and Job, 1988; Sacchett and Humphreys, 1992; Warrington and Shallice, 1984; Caramazza and Shelton, 1998; Lambon-Ralph et al., 1998; see Saffran and Schwartz, 1994, for a review). In a substantial number of cases this deficit has been observed in patients who suffered from herpes simplex encephalitis (Warrington and Shallice, 1984; Barbarotto et al., 1996; De Renzi and Lucchelli, 1994; Gainotti and Silveri, 1996; Laiacona et al., 1997; Sartori and Job, 1988, Sartori et al., 1993 a, b). Along with a deficit affecting living things, an impairment altering the semantic ability to deal with foods has been often reported (Warrington and Shallice, 1984; Eslinger et al., 1993; Silveri and Gainotti, 1988; Sheridan and Humphreys, 1993).

However, although a great number of evidence supports the first reports of category-specific deficits, an unequivocal consensus about its theoretical account is not achieved yet. Several reasons can be raised in order to justify the huge variability within clinical evidences and the wide range of theoretical proposal put forward by researchers. A remarkable number of aetiologies were reported to give rise to category-specific deficits: the huge differences as regards to lesion sites and general neuropsychological outcomes may account for some of the variability found in the clinical description of patients' semantic memory cognitive disruption. Moreover, highly different tasks and unmatched sets of stimuli were adopted in studies of category-specificity, leading therefore to a preponderant difficulty in evaluating and comparing the major findings from patients' performance.

A wide variety of theoretical accounts of category-specific deficits for living things have been put forward by researchers in the past decades. An explanation in terms of different ways of processing critical properties of concepts pertaining to either living things or man-made artefacts within the semantic memory system has been originally proposed by Warrington and Shallice (1984): a process relying relatively more upon the appreciation of sensory features would support the elaboration of living things concepts, while the processing of man-made artefacts would imply to a greater extent the analysis of functional attributes. Hence, in the authors' view a major role in the emergence of category specific deficits is claimed for the differential type of conceptual features on which the semantic processing will be based. A direct support to this view is provided by computational studies. A differential weight in favour of perceptual properties relative to functional attributes underlies the elaboration within the living things category, whilst the reverse proportion between the two types of semantic features underpins the processing of the man-made artefacts class; when perceptual semantic properties are lesioned, a greater deficit for living things arises in the model (Farah and McClelland, 1991; Small, Hart, Nguyen and Gordon, 1995).

This position has been recently challenged by Caramazza and Shelton (1998). The authors claim that the semantic knowledge is organised into distinct and independent conceptual domains such as animals and plants, on the one hand, and tools on the other. In the authors' proposal, the living things class (and perhaps foods) should be considered as a semantic category developed and organised by evolutionary pressures; this domain is considered to be independent from the man-made artefacts class. At variance with Warrington and Shallice's (1984) position, the role of different types of semantic features —in Caramazza and Shelton's view related to biological properties in the case of living things and function with respect to man-made artefacts—, is claimed to be not critical for the differentiation between semantic domains. In these authors' view, instead, the categorical distinction between the two domains of living things and man-made artefacts is held to be intrinsically fundamental.

An alternative account of category specific deficits which stresses the influence of factors such as frequency, familiarity or visual complexity was proposed by a considerable number of investigators (Funnell and Sheridan, 1992; Funnell and De Mornay Davies, 1996; Stewart et al., 1992; Parkin and Stewart, 1993; Gaffan and Heywood, 1993). Despite the fact that such lexical and perceptual factors might play an influential role on patients' performance, category specific deficits affecting living things have been confirmed even when these variables were taken into control (Shallice, 1996). In addition, these positions cannot hold as respect to the explanation of the increasing amount of reports of patients showing a selective deficit disrupting the semantic knowledge of the man-made artefacts class, in contrast to a relatively preserved knowledge of the living things category (Warrington and McCarthy, 1983, 1987; Moss and Tyler, 1997; Sacchett and Humphreys, 1992; Hillis and Caramazza, 1991). As shown by Hillis and Caramazza (1991) a double dissociation characterised the performance of their two patients, one, PS, selectively impaired, the second, JJ, selectively spared with respect to animals. Furthermore, patient PS showed much a better performance with categories not including animals and vegetables (92% correct) with respect to animals (45% correct) and vegetables (29.7% correct), while the opposite pattern was found in the case of patient JJ, who had a better performance with animals (81.4% correct) than with non animals (12.4% correct) categories (the data are mean percentage values calculated over 7 subsequent naming sessions). The fact that the authors adopted the same stimulus set to assess their patients' semantic knowledge, and that a clear dissociation emerged when the two patients were compared, is a further strong evidence in favour of the rejection of an interpretation of category-specific deficits in terms of differential tasks or stimulus difficulty. However, this double dissociation might be accounted for by appealing to differences between categories in the degree of processing demands.

In more recent times, a concrete effort has been made in order to account for category-specific deficits in terms of a semantic "featural" perspective. Patients have been described who presented a category specific deficit for living things without showing a selective impairment involving their ability to process sensory attributes of concepts relative to functional-associative features (Lambon-Ralph et al.,1998, patient DB; Laiacona, Capitani and Barbarotto, 1997; Moss, Tyler, Durrant-Peatfield and Bunn, 1998). On the other hand, the case of a patient had been recently reported who demonstrated an inability to process visual semantic attributes, although she did not show a category specific effect for living things (Lambon-Ralph et al.,1998, patient IW).

These findings therefore suggest the need of redirect, at least partially, the current theories of category specificity, in order to achieve a more exhaustive theoretical account of the "classical" category specific as well as the "novel" attribute specific deficits (Lambon-Ralph et al., 1998; Tyler, Moss, Durrant-Peatfield, Levy, in press).

1.2 Main proposals and expected conclusions

1.2.1 Knowledge of living things, man-made artefacts and "mass" kinds: semantic categories and conceptual properties

The present study investigates the category-specific deficit associated to living things in a group of patients characterised by the same aetiological disease, having all suffered from a probable episode of herpes simplex viral encephalitis. This choice was taken in order to grant, at least to some extent, the reliability of the findings within the experimental group, and overcoming the plausible influence of disease type on patients' performance.

In this work an extensive assessment of the status of patients' semantic memory system as regards to the broad knowledge of two classical semantic categories, living things and man-made artefacts, was carried out, along with a parallel investigation of the categorical knowledge of a novel class of stimuli, such as different "mass" kinds, thought to be relevant in addressing some fundamental issues actually debated by contrasting theoretical accounts of category specificity (sections 5.3 and 5.4). Patients' assessment was obtained through the adoption of large and, as much as possible, balanced sets of stimuli, used to devise a series of tasks aimed at tapping patients' semantic competence both in the verbal and visual modalities, as regards to stimulus presentation and response mode. The exam of domain-related knowledge was carried out, in the first two experimental sections (5.3 and 5.4), with the specific purpose of achieving a basic picture of semantic memory deficits in the patients group and, particularly, in patient MU, which was the only one showing a well defined category specific deficit, affecting to a great extent the living things class with respect to man-made artefacts.

One major objective of the two first experimental investigations (5.3, 5.4) aimed at ascertaining the existence of a relation between the semantic categories of living things and "mass" kinds. In the light of Warrington and Shallice's (1984) position, the cognitive elaboration within the semantic memory system of semantic categories such as living things and man-made artefacts should be accomplished in terms of the differential weight conceptual attributes, such as functional and sensory features, place on the definition of a concept. In the authors' view, man-made artefacts should be conceptually processed more through an analysis based on functional properties. In fact, artefacts directly suggest the use which they have been made for. Moreover, shape is the unique visual characteristic which might intervene in their differentiation from one to the other. The role the shape of an object might have in allowing the distinction among members of the man-made artefacts category has been stressed by De Renzi and Lucchelli (1994) and Tyler and Moss (1997), inasmuch as form is tightly linked to the function an object has.

However, in the case of living things a primary role with respect to their semantic processing could be possibly played by sensory features (Warrington and Shallice, 1984). As a direct implication of this argument, other semantic categories, such as "mass" kinds, which should be better defined through the appreciation of sensory properties than that of other types of semantic attributes, might present with a behaviour closely comparable to that shown by living things. The observation of a similar behaviour in the case of living things and different classes of the "mass" domain would suggest an intimate relation between these two semantic categories, inasmuch as they might rely on the same semantic processing. In fact, different members belonging to the class of living things might be principally distinguished by their typical colour, texture and other general surface characteristics —e.g. a zebra can be differentiated from a horse on the basis of the colour and the presence/absence of stripes on the coat. Their shape instead might not be of much help for visual identification, since many members of the living things category share a similar form. Moreover, the majority of members belonging to the living things class does not directly suggest any peculiar function (e.g. "what an animal can do", or "what it can be used for"), while this comes true for many man-made artefacts exemplars.

Also "mass" kinds lack of a characteristic shape which could allow them to be differentiated from other members of the same category, being instead visually recognised mostly through their texture and colour. Their function, in contrast, cannot be strictly associated to a highly specific context —although it has to be stressed that "mass" items usually have some function. Furthermore, although they are generally manipulable, no specific, distinctive, action can be linked to their use. If, on the one hand, function, or better manipulability, is linked to the form of an item (Buxbaum and Saffran, 1998), and, on the other, sensory attributes are involved in the distinction and differentiation of exemplars within this category, then "mass" should behave like living things.

Therefore, the performance of a patient, MU, showing a category specific deficit for living things was widely examined: the specific effort was pursued at verifying whether his poor performance with respect to the living things domain was comparable to that regarding the "mass" class, in contrast with a relatively spared performance with man-made artefacts. Furthermore, the pattern of impairment affecting living things, whatever is its degree of gravity, should be closely mirrored by patient's performance with "mass". Therefore, category specific deficits for living things of minor or minimal magnitude, as those shown by other patients studied in this work, should lead to comparable, and therefore less severe, levels of impairment as respect to the "mass" category.

A second, equally fundamental, issue of the present work is closely linked to the assumptions discussed above in this section. The assessment of patients' category specific deficits was also performed under a quite different theoretical and empirical perspective. The conceptual knowledge of the living things and man-made artefacts domains is held by some authors to be influenced by cross-categorical semantic factors, which are thought to underlie or support the processing of such highly distinct categories (Warrington and Shallice, 1984). Therefore, the knowledge associated to functional and sensory properties of stimuli belonging to any of the three basic aforementioned semantic classes was also assessed through the development of new tasks (section 5.5). In keeping with Warrington and Shallice's (1984) view, a selective deficit affecting cross-categorically the knowledge of sensory properties should also be found in patient MU. A much more severe impairment should be observed in the case of the living things and "mass" categories. However, a deficit affecting sensory knowledge should be reported also for man-made artefacts, even though to a lesser extent and gravity (Farah and McClelland, 1991).

In order to tap patients' featural knowledge, two tasks —the first aimed at probing the spontaneous production of semantic properties (sections 5.5.2 and 5.5.4), and the second assessing the ability to verify the appropriateness of semantic attributes associated to a large series of stimuli (sections 5.5.6 and 5.5.8)—, allowing a large and complex array of analyses were developed.

1.2.2 Semantic features: functional and sensory notions revised

In the light of the above considerations, a strictly related issue was addressed in the last experimental section of this work (section 5.6). In fact, previous studies of category specificity and the core investigations carried out in this work as well, posit on the idea that semantic notions, such as functional and sensory properties, are based on well defined meaning. However, such a general consensus could not correspond to further possible fractionations of the meaning implied by these semantic properties. A careful examination of the notions related to functional and sensory attributes may therefore reveal that these are not unitary concepts. Therefore, an effort was made in the last experimental part in order to detach to a deeper level the notions related to sensory and functional semantic attributes.

In the literature, a massive effort was spent in order to distinguish between these two types of semantic attributes: sensory and functional features. Whereas there is a general agreement as far as sensory features are concerned, being typically associated to the visual (i.e., colour and texture), auditory and tactile properties of objects, a further attempt to distinguish between the knowledge of general vs. specific sensory features of animals has been accomplished in section 5.6.2 of the present work. General sensory features (e.g. lungs-breathing; mouth-eating) are widespread characteristics, and they have been associated to their biological relevance for live survival (Tyler et al, 1996; Tyler and Moss, 1997). On the other hand, specific sensory features (e.g. horn, tail) are usually thought to be fundamental for the distinction among exemplars of a category. It has been shown in previous studies as the knowledge of the two types of sensory properties might be differentially impaired in patients with category specific deficits for living things, being usually more intact the knowledge of general features with respect to specific ones (Tyler and Moss, 1997; Tyler et al., 1996). Therefore, in this study the knowledge of the single patient MU about general and specific sensory features of animals was probed (section 5.6.2.1).

However, both widespread sensory features of animals —such as having heart, lungs, eyes etc.— and specific sensory features —such as hooves, horn, claws etc.— may be linked to peculiar functions, although, in the latter case, not always associable to fundamental biological functions. Obviously, in this latter case the strength of the link "specific feature-function" will be much more feasible than in the case of "shared features-biological functions" of the type suggested by Tyler and colleagues. Moreover, specific sensory features are generally less frequent and less familiar than general sensory features, and these factors might strongly influence and differentiate their behaviour, without necessarily implying that a connection between sensory and functional aspects is not present. Consequently, an attempt to assess the functional knowledge associated to sensory features was carried out in experimental section 5.6.2.2 of this work.

The preceding point, regarding the assessment of the functional properties of sensory attributes, is closely related a to further issue: function and manipulability notions have been frequently mixed in previous works on featural semantic knowledge. However, there might be ground for a distinction between these two aspects (Buxbaum and Saffran, 1998). Sensory properties of animals are not "manipulable", at least in the sense of "the action we can perform on an animal's sensory feature". However, a minor number of sensory attributes of animals can undoubtedly perform highly distinctive "self-generated" movements: the knowledge of the action a sensory attribute can accomplish, though it is not completely overlapping to the notion of manipulability, has not been investigated yet. Therefore, the role this type of semantic information might play during the processing of perceptual features of animals was also examined (section 5.6.2.3).

On the different ground of the semantic featural knowledge associated to man-made artefacts, the label "function" has been adopted by researches in reference to a wide array of semantic properties, such as the use of an object, some associative and encyclopaedic information, or the way by which an object is used, leading to a widespread confusion about the real semantic properties they were investigating. In Warrington and Shallice's (1984) theoretical account of category specific deficits, the identification of man-made artefacts is held to rely on the processing of functional features, but the meaning of "function" has never been directly addressed in studies of category specific deficits. Only in recent times a distinction has been proposed between the semantic information related to "what can be done with an object" —the object function— and that linked to "the action an object suggest" —affordance to action— (Buxbaum and Saffran, 1998). However, a similar suggestion was put forward already by Warrington and McCarthy (1987): these authors hypothesised that differential weighting values for multiple sensory channels (visual vs. sensory/motor information) might play a role firstly in the acquisition of different categories of knowledge, and secondly in the categorical organisation of systems subserving semantic knowledge. In a recent study, Buxbaum and Saffran (1998) found that aphasic patients with apraxia were more impaired when asked to compare equally manipulable objects (i.e. piano, type-writer) with respect to objects with similar function (i.e. radio, record player). These authors suggest that the knowledge of the manner in which objects are manipulated may be impaired relative to the knowledge of the function an object has.

An effort directed to achieve an unequivocal clarification of the role played by two different kinds of "functional" information was made in the last experimental section of this work (5.6.4). A series of tasks was devised with the aim of disentangling the "use of an object" (what an object can be used for; what an object can do —pure function) from the "way in which an object can be used" (the action/s associated to the use of an object —affordance to action). The notion of "pure function" might characterise, though to various degrees, different semantic domains, such as man-made artefacts, living things and "mass". Thus, the sparing of this type of semantic information was expected to arise in patient MU over a wide range of tasks. However, man-made artefacts can be associated to both types of information, "pure function" and "affordance to action", insofar as they usually have a specific use and they are manipulated in a certain way. In contrast, living things or "mass" cannot be easily associated to a peculiar action to be performed on. Moreover, some objects might be associated to a precise function but characterised by a wide array of actions; other objects tend instead to be associated to a unique action. Therefore, the differential role of the two types of semantic information, that of object function (section 5.6.4.3) and that related to object action (section 5.6.4.4), was also assessed in the present work, and their influence on patient's performance in tasks devised with this specific purpose was examined.

However, the empirical evidence and theoretical consequences which could be drawn from this last series of experimental investigations (section 5.6) must be taken just as provisional and preliminary attempts at segregating to finer gradients notions which might influence, methodologically and theoretically, the future studies in the field of category specificity.

Chapter 2: Herpes simplex encephalitis patients

2.1 Introduction

The present study aims at investigating from a neuropsychological perspective the organisation of the semantic memory system in patients with neurological damage. The principal purpose of this work is a wide-ranging study of category-specific deficits that affect patients' semantic knowledge of the living things conceptual domain. Category specific deficits for living things have been reported, in a limited number of cases, to be a neuropsychological consequence of a viral encephalitis due to herpes simplex virus infection (HSE). This pathology is commonly associated to cerebral lesions which affect the inferior and medial regions of the temporal lobes and the orbital parts of the frontal lobes.

Therefore, in this work a group of patients who had suffered from an episode of encephalitis of probable herpes simplex viral origin has been examined. The assessment of the status of their semantic memory knowledge has been performed, and particular effort was devoted to the investigation of the category specific phenomenon the group of HSE patients shows.

This chapter presents an overview focused on the characteristics of the disease process and the principal neuropsychological deficits following from an episode of herpes simplex virus encephalitis.

2.2 Neuropathological description

Herpes simplex encephalitis is one of the most common and severe forms of acute encephalitis. Unlike other less common forms, this type of encephalitis can affect people in every period of the year and is widespread throughout the whole world. It can affect people of any age, and is usually caused by the herpes simplex virus type 1 (HSV-1), responsible for the common lesion to the oral mucous membrane: only in rare cases, however, does an encephalitis develops. The herpes simplex virus type 2 (HSV-2) usually leads to an encephalitis which affects children in the neonatal period (Adams and Victor, 1994).

Two hypotheses have been put forward regarding how the virus enters the brain. The virus may be latent in trigeminal ganglia, and its reactivation can infect the nose and the olfactory tract; a second hypothesis however states that infection might be activated at the level of the trigeminal ganglia, spreading then through the anterior and median parts of leptomeningi (Adams and Victor, 1994).

The prognosis depends essentially on the patient's age and his/her state of consciousness at the beginning of treatment. If the patient is unconscious, the prognosis is commonly poor. On the other hand, provided that the treatment starts within 4 days from the symptoms onset, the probability of survival reaches 92% in patients treated before the onset of coma (Adams and Victor, 1994).

The long-term neurological effects are, in a large preponderance of cases, extremely severe: a very dense amnesia, global dementia, epileptic seizures and dysphasia.

2.2.1 Clinical features

Viral encephalitis is often combined with signs of meningeal or spinal cord infections. Prodromal symptoms evolve in several days, and are typical of the majority of acute encephalitis forms: fever, headache with or without meningism, photophobia, malaise, nausea and vomiting. These symptoms are usually followed by a variable pattern of altered mental status, hemiparesis, aphasia and seizures, leading in some cases to a progressive impairment of consciousness, such as lethargy, stupor and coma (Malessa and Tyler, 1996). In many patients these symptoms are preceded by others, which highlight the concomitant neurological affection of infero-medial temporal and frontal lobes: hallucinations related to taste and of olfactory type, anosmia, temporal seizures, alterations of personality, bizarre or psychotic behaviour, aphasia and hemiparesis (Adams and Victor, 1994). During the initial phases of the disease, a disturbance of memory is rarely reported, becoming however much more prominent only later, during recovery. During the first 24-72 hours one or both temporal lobes might show oedema, and can herniate through the cerebellar tentorium, causing profound coma and preventing normal breathing. Often the cerebro-spinal fluid (CSF) is characterised by lymphocytic pleocytosis; sometimes a considerable amount of neutrophils can be observed. The protein content in CSF is commonly enhanced, and only rarely the liquor glucose is less than 40mg per 100ml. The haemorrhagic nature of the lesion is reflected by a large number of red corpuscles. It is often not possible to isolate the herpes simplex virus from the CSF (Adams and Victor, 1994).

2.2.2 Diagnosis

As for the majority of viral infections of the CNS, the clinical features of herpes simplex viral encephalitis can be identified with certainty in only 30% of the cases (Malessa and Tyler, 1996). The diagnosis presents a number of difficulties: common, although not unique features of this type of encephalitis are the alterations of the EEG: repetitive sharp slow-wave discharges at 1-5 seconds intervals are localised in temporal regions, often combined with a slowed background activity. The analysis of the lesion pattern through CT and MRI scans is usually valuable. Cerebral lesions are characterised by a haemorrhagic necrosis, mostly localised in the inferior and medial parts of the temporal lobes, and in the orbital regions of the frontal lobes. The CT scan may remain normal during the first 3 days after the onset of neurological symptoms, then hypodense lesions appear in the fronto-temporal regions. Many patients' MRI scans show areas of increased signal on T2-weighted images in frontal and temporal areas as early as 2 days after onset. These abnormalities can be detected within days from the onset of illness and may be present even when the CT scan is normal or shows only minor abnormalities The peculiar localisation of lesions might be explained by the way the virus enter in the brain (section 2.2).

However, the most certain method of diagnosis implies the use of fluorescent antibodies and of viral cultures of cerebral tissue acquired by biopsy. The recent introduction of PCR (polymerase chain reaction) allows the amplification and detection of even minute quantities of viral DNA or RNA. This technique has been proven to be a useful diagnostic mean during the first days of the disease, making unnecessary the use of biopsy.

2.2.3 Treatment

The therapy usually adopted in the cases of herpes simplex virus encephalitis involves the use of the antiviral agent Acyclovir, which is a deoxyguanosine analog that is effective against both HSV-1 and HSV-2. Acyclovir is administered by intravenous infusion at the dose of 10mg/kg body weight at 8 hours intervals, for 14 days, in order to prevent relapse. In the rare cases of relapse after Acyclovir therapy, however, the treatment might be continued with vidarabine (adenine-arabinoside) or foscarnet, a pyrophosphate analog. The risk of mortality in Acyclovir treated patients is currently below 25% (Malessa and Tyler, 1996).

2.3 General neuropsychological deficits following HSE

Patients who suffered from HSE were often studied because they show, in a limited number of cases, a peculiar disturbance of the semantic memory system, particularly, a category specific deficit which affects their conceptual knowledge of the living things domain. In contrast to the selective disruption of the semantic knowledge of concepts associated to the living things class, such as animals, fruits and vegetables and, in some cases, the category of food, these patients show a relatively unimpaired knowledge of the man-made artefacts class. This classical pattern of preservation (man-made artefacts) and impairment (living things) of the semantic knowledge of the two broad domains has been originally described by Warrington and Shallice (1984) in four patients who all suffered from an episode of HSE. After the seminal work of Warrington and Shallice, an increasing number of cases showing category specific deficits for living things relative to artefacts has been reported in the literature of the last two decades.

However, HSE patients present a complex series of neuropsychological deficits that affect to various extent other cognitive skills, such as memory, executive functions, language and visual processing. A survey of general neuropsychological deficits arising as a consequence of HSE will be presented below in this section.

Although HSE patients often show neuropsychological impairments, in a large group study 12% of the HSE patients was found to be in general cognitively intact (Hokkanen et al., 1996b), with no severe intellectual and logical functions impairments with respect to non-HSE encephalitic patients.

2.3.1 Memory functions

A series of group studies demonstrated that the most relevant symptom of HSE survivors consists of a memory deficit characterised, at discrepant degrees of severity, by either anterograde, more frequently (Utley et al., 1997), or, less frequently, retrograde amnesia (Utley et al., 1997). However, caution is recommended in considering amnesia as a uniform phenomenon directly consequent an herpes simplex encephalitis (Hokkanen et al., 1996a).

Usually, impairments in digit or word span are not markedly serious. Short term memory was found to be relatively well preserved on HSE patients both in group (Butters and Cermak, 1980) and in single case studies (Cermak and O'Connor, 1983; Butters, Miliotis, Albert and Sax, 1984).

Anterograde amnesia in HSE patients was often assessed in comparison to groups of Korsakoff amnesic patients. In group studies, HSE patients showed a more rapid forgetting rate with respect to Korsakoff patients (Lehermitte and Signoret, 1972; Parkin and Leng, 1993); the same finding was also reported in a single case study by Parkin (1984). Furthermore, immediate and delayed free recall and recognition were also reported to be highly defective in an HSE patient (Cermak and O'Connor, 1983).

The assessment of retrograde amnesia in HSE patients showed a generalised variability as respect to the extension of memory loss which was estimated, in a group study of Foletti, Regli and Assal (1980), to range from 3 months to 20 years (reported in Parkin and Leng, 1993). In a series of single case studies, a large variability was also found in HSE patients' ability to deal with past information related to either public or personal events. A deficit affecting the retrieval of both public and autobiographical events was reported (Cermak and O'Connor, 1983; Damasio and Van Hoesen, 1985). However, an advantage for the retrieval and learning of personal facts relative to that of public events was described by De Renzi et al. (1987). Moreover, the selective sparing of unconscious access to stored facts was also reported (Hanley et al., 1989), in contrast to a widespread difficulty in overt recognition tests. In addition, the preserved ability to learn the meaning of new words, entering the vocabulary in the time periods from which the patient could not overtly recall personal events, was described in a patient with dense retrograde amnesia, affecting both public and autobiographical events (Warrington and McCarthy, 1988).

A series of other single case studies confirms the preservation of implicit memory in HSE patients, who showed a normal learning of pursuit rotor (Cermak and O'Connor, 1983), of classically conditioned eyeblink response (Warrington and Weiskrantz, 1982), and of learning new tunes on the piano (Starr and Phillips, 1970).

Finally, patient SS (Cermak and O'Connor, 1983) was able to retain novel verbal information at an implicit level.

An outline of the memory function profile of a group of HSE patients, who showed a category specific deficit for living things, is presented below (see table 1, section 3.2.2).

2.3.2 Executive functions

A formal assessment of frontal symptoms in HSE patients has been rarely reported in the literature. In a group study, executive functions were found to be less severely damaged than memory skills: however, mild problems were observed in the Cognitive Estimation test, and evidence of an impoverished planning was also mentioned (Utley et al., 1997). A remarkably defective performance on the Cognitive Estimation task was however reported by Leng and Parkin (1988) in their patients group, whereas WCST only led to a mild degree of impairment.

Behavioural changes, such as some disinhibition and palilalia have been rarely described; confabulatory behaviour was also noted in rare cases, but it does not seem to be a very prominent symptom in HSE patients (Parkin and Leng, 1993). However, in a study by Hokkanen et al. (1996b), 65% of their HSE patients group showed persisting mood or personality changes, including euphoria, maniac behaviour, aggressiveness, irritability and depressive symptoms, although no signs of Klüver-Bucy syndrome were observed.

2.3.3 Language functions

The assessment of language skills presents with a varied pattern of performance across HSE patients (see table 1, section 3.2.2) for an outline of language deficits in HSE patients with category specific deficits). Some of the patients showed marked expressive speech difficulties, while others were fluent speakers; in general, however, word finding difficulties have been often reported. Word comprehension was also found to be impaired to various degrees of severity. Dyslexic and dysgraphic symptoms have been also frequently reported. However, in a study of a series of subsequent unselected survivors after HSE, language skills were found to be only mildly affected, with a prevalence for anomic problems (Utley et al., 1997). Nonetheless, it has to be pointed out that the language skills of herpes patients have been infrequently thoroughly investigated, because of the major interest addressed to their performance in semantic memory tasks which could highlight a selective category specific deficit.

2.3.4 Visual perceptual functions

An argument similar to that made for language functions can be advanced in the case of visual perceptual skills. HSE patients' performance in visual tasks have often been probed, with the major purpose of partialling out severe visual perceptual or recognition problems, which could otherwise account for patients' deficits in semantic memory tasks employing visual material. The presence of visual perceptual deficit in HSE patients is mentioned by Hokkanen et al. (1996b) in their group study. However, there are very few comprehensive investigations of HSE patients' visual perceptual abilities. Anyway, as can be observed in table 1 (section 3.2.2), whenever it was probed, an intact visual perception was reported twice as frequently as damage.

2.4 Main findings and general discussion

In this chapter the principal features of HSE are discussed. This viral infection results in a rapid necrotic process that affects in a first instance the structures of the temporal and orbito-frontal cortices, then, if the process is not blocked by pharmacological treatment, it attacks also the subcortical regions. The most frequently involved brain areas in HSE patients are the anterior, medial and inferior portions of one, or, more often, both temporal lobes, and the ventro-medial and basal regions of the frontal lobes. Damages to the hippocampus and the parahippocampal formation are also present.

HSE patients are often studied because they may present category specific deficits for the living things class, in contrast to a spared performance in the case of the man-made artefacts domain. However, the most general neuropsychological outcomes of HSE infections concern an impairment of memory functions, leading to either anterograde or retrograde amnesia, or both, in contrast to the usual preservation of short term memory. Language deficits are sometimes reported, and are generally associated to word-finding difficulties, although more severe defects may be observed in isolated cases, affecting the linguistic production or comprehension; additional problems may be due to dyslexia and dysgraphia. Executive functions have received little attention: in HSE studies, however, deficits are often mentioned, although not thoroughly investigated. Visual perceptual skills are preserved in most of the cases, though impairments have been described in some patients: however, it seems largely accepted that perceptual deficits rarely influence HSE patients' performance to such an extent that they could wholly account for category specific impairments.

Chapter 3: Semantic memory system and category specificity

3.1 Organisation and concept representation in the semantic system

Within the field of cognitive studies of long–term memory, an influential position was put forward by Tulving in the early seventies of the last century, who drew a distinction between two different memory systems: the first one, the episodic memory system, devoted to the storage of information related to public events and personal episodes, temporally and spatially characterised, and the second one, the semantic memory system, committed to the organisation of our knowledge of "...words and other verbal symbols, their meaning and referents...relations among them" and "the manipulation of these symbols, concepts and relations" (Tulving, 1972). Although Tulving conceived the semantic memory system as strictly linked to our use of language, it was later considered as a more general knowledge base, necessary for language and an overwhelming number of cognitive processes as well (Kintsch, 1980). Moreover, the rigid dichotomy held by Tulving was subsequently questioned, leading to the view of a reciprocal interaction between these two memory systems (McKoon, Ratcliff and Dell, 1985).

The huge variety of theoretical models of the semantic memory proposed in the past years focused on two main issues: the organisation of semantic knowledge and the format or modality characterising the representation of concepts.

A hierarchical organisation of the semantic system was early proposed by Collins and Quillian (1969).

They held the semantic system to be a network model in which conceptual nodes are hierarchically structured into different levels: subordinate nodes are thought to be at the base of the hierarchy, whereas superordinate concept nodes are at the top. Concept properties are linked to their respective representations at each level of the hierarchy. The process of semantic determination of concepts goes from the basic levels of the hierarchy to the top. A direct consequence of this view is that a damage affecting the low-level subordinate structure should impair the access to high-level information.

However, several findings from patients with semantic deficits are in conflict with this prediction, since the patients' loss of conceptual knowledge usually impairs the subordinate levels of representation, leaving instead spared superordinate information (Warrington, 1975; Schwartz et al., 1979).

The attempt to account for the selective advantage of the superordinate information led to the proposal of a model based on the spreading of activation as a critical organisation principle within the semantic system (Collins and Loftus, 1975). Concepts are localised in the semantic network on the basis of their relative semantic distance: therefore, the nodes representing concepts are at different distances from one to the other, and their organisation influences the way the activation spreads in the network. When two concepts are stimulated, activation spreads through the nodes until their two related nodes are connected. The spreading time is therefore dependent on the semantic distance which characterises the relation between the two concepts. Correlated concepts are localised close together in the semantic network. In Collins and Loftus's view thus, prototypical concepts are near to their related superordinate, and are therefore more likely to activate the superordinate than less prototypical exemplars. Therefore the advantage of superordinate information with respect to subordinate is held to be due to the process of activation, which spreads from exemplars nodes to all the elements belonging to the same category, and by each of these nodes the activation spreads to the superordinate node, that receives therefore the highest amount of activation with respect to subordinate nodes.

A computational model put forward by Rieger (1978, quoted by Shallice, 1988) proposes instead that the meaning of a concept is processed by an expert program which is held to select among alternative meanings of that concept. The context in which a given concept is presented activates alternative expert programs during the process of meaning assignment. The initially accessible information is held to be the concept category.

Within connectionist models, meaning is represented by a set of distributed characteristics variously linked to the concept. The superordinate information depends on the confluence of elements which are common to a wide range of exemplars. The representation of a concept will always depend on the specific neural activation profile that arises from the activity of singular interconnected units (McClelland and Rumelhart, 1985). This view can thus account for the availability of superordinate information and its resistance to brain damage.

A long lasting debate has been concerned with whether the semantic memory system has to be conceived as a unique and amodal system or, in contrast, is organised into multiple modality-specific components. A first group of theories proposes the existence of a unique system, which is devoted to the representation of concepts through a pictorial code (see Glaser, 1992, for a review). This type of account allows the explanation of phenomena linked to mental imagery and to the advantage for the memory of pictures as opposed to words (Paivio, 1969). However, the modality by which the pictorial code interacts with verbal symbols is not explained by this type of theories. Furthermore, also abstraction and generalisation processes are not accounted for by the assumptions made by the theories.

A development of these earlier accounts is the dual coding approach (Paivio, 1978), which claims that a pictorial code will be engaged as far as concrete, perceptual properties of concepts are concerned, whereas a verbal code will process the abstract and linguistic characteristics of semantic representations.

A central, abstract and amodal system was proposed instead by Seymour (1976), in which the storage will depend on a prepositional code, and memory content will be accessible through the engagement of two systems devoted to re-coding in terms of either pictorial or verbal format. In more recent times, however, it has been put forward the proposal (Glaser 1992) that the long-term memory system is subdivided into two central components: a semantic memory system, based on abstract nodes representing the pictorial characteristics of concepts, and a non-semantic lexicon, containing the representation of the morphemes of language. Therefore this theoretical position is based on the idea that the pictorial system is embodied into an abstract and non-verbal semantic system, and that the verbal system is non-semantic.

However, the increasing amount of findings on brain damaged patients with modality-specific dissociations led to the idea that these data can be better accounted in terms of a multiple-component system.

Warrington and Shallice (1979) provided evidence for a distinction between verbal and visual memory subsystems (see also Warrington, 1975; Chertkow et al., 1992). Furthermore, brain damaged patients with semantic dementia have been reported to show a semantic loss, demonstrable through verbal and non-verbal tasks, but with a perfect knowledge of object use (Schwartz et al., 1979; see also Holland et al., 1985; Marin et al., 1983; Schwartz and Chawluk, 1990). Studies on optic aphasia (Beauvois, 1982), auditory aphasia (Denes and Semenza, 1975) and bilateral tactile aphasia (Beauvois et al., 1978) also provide further evidence for multiple semantic systems. The debate on whether the semantic system has to be considered as multi-componential or a unitary system has been proposed in two recent studies. Lambon-Ralph and Howard (2000) described a patient, IW, who showed poor picture naming and impaired verbal and non-verbal comprehension, whereas the comprehension of pictures and objects remained unaffected. The authors consider their findings as evidence for a unitary semantic system. They refer to the findings of a functional imaging study (Vandenberghe et al., 1996) in which both word and picture comprehension led to the activation of a large network, involving the left superior occipital gyrus, through the middle and inferior temporal cortex, to the inferior frontal gyrus. Lambon-Ralph and Howard (2000) therefore hypothesise that their patient's deficit could be accounted in terms of an impairment to a unitary semantic system, because her deficit was found both for verbal and non-verbal comprehension, rather than to a selective damage to a multi-component system, affecting specifically some components. In the authors' opinion, the unitary-system hypothesis explains the deficit to the verbal and, although to a minor extent, the non-verbal components in terms of differences which underlie the translation between surface form and meaning in the case of words (where the access to the word form is based on abstract relationships) and pictures, which have a direct non-arbitrary (quasi-semantic) access to the conceptual system.

However, substantial support to the view of a multi-component system is provided by a study of Druks and Shallice (2000). The authors described patient LEW, who was severely defective in naming tasks involving pictures of both objects and actions. However, the patient showed unaffected performance in naming to verbal descriptions. His modality-specific naming deficit was not accountable in terms of a visual perceptual impairment, and, more importantly, he was able to access conceptual knowledge of both pictures and words. Furthermore, since the patient could show a quite preserved access to semantic knowledge from both pictures and words, Druks and Shallice provide evidence against an interpretation of the deficit in terms of an impairment of the mapping between the visual input and an amodal semantic system, suggesting rather that LEW's deficit is much more easily accountable in terms of the multiple semantic theory. His impairment is held to affect the process required to transform semantic representations of visual input into a "preverbal message" (in Levelt's, 1989, terms), necessary to address lemma selection. On the other hand, LEW's good performance in naming to verbal descriptions would suggest that, in the case of a verbal input, semantic representations "satisfy the conditions for the restricted preverbal message necessary to drive lemma selection", without requiring any type of further transformation process.

Therefore, the findings of modality-specific dissociations have led support to the argument of a highly structured multi-modal system, based on different modality-specific subdomains (Shallice 1988; McCarthy and Warrington, 1990). In this framework, semantic representations will achieve their structure on the basis of their intrinsic nature and the modality of acquisition process.

However, the most remarkable evidence supporting the view of an internal fractionation within the semantic memory system is offered by the large amount of findings from brain damaged patients affected by category specific impairments.

3. 2 Category specificity effects

3.2.1 Introduction

Several patients were described in the past times as having selective deficits or preservation of either production or comprehension as regards to the most disparate semantic categories.

Dissociations were reported with respect to the concrete vs. abstract words distinction (Warrington, 1975; Warrington, 1981; Warrington and Shallice, 1984); words vs. pictures (McCarthy and Warrington, 1988); object vs. action (McCarthy and Warrington, 1985); proper names vs. common names (Semenza and Zettin, 1988, 1989; Ellis et al., 1989; McNeil et al., 1994; Lucchelli and De Renzi, 1992; Hittmair-Delazer et al., 1994; Semenza et al., 1998); proper names with a unique vs. non-unique referent (Shallice, 1993); a sparing of geographical terms naming (McKenna and Warrington, 1978) and comprehension (Wapner and Gardner, 1979; Goodglass and Butters, 1988). Naming body parts was shown to be selectively affected (Sacchett and Humphreys, 1992) or spared (Goodglass et al., 1986), and a similar dissociation was also reported for comprehension of body parts which could be either impaired (Ogden, 1986; Semenza, 1988), or preserved (Riddoch and Humphreys, 1987). A selective disturbance of colour naming was observed (Beauvois, 1982; Beauvois and Saillant, 1985) as opposed to preservation (Yamadory and Albert, 1973; Goodglass et al., 1986), and a deficit affecting the comprehension of colours was also described (Yamadory and Albert, 1973). A comprehension deficit for household objects was also described (Yamadory and Albert, 1973), as well as an impairment for small manipulable objects as respect to large outdoor objects (Warrington and McCarthy, 1987).

However, the category-specific deficit for living things with respect to man-made artefacts is among the most typical and was deeply investigated in the last two decades of twentieth century. At variance with the category specific deficits shown by patients who have suffered from HSE, which are, in the large majority, affecting patients' semantic knowledge of the living things category as a whole, and involving production and comprehension processes both in the verbal and visual modalities, patients with different sorts of pathologies often present a much varied pattern of deficits. In some cases, the semantic deficit impairs both the production and comprehension of the affected category, while, in others, difficulties restricted to the output side are reported. Furthermore, patients have been described to show semantic impairments selectively affecting a single modality of presentation. Moreover, selective fractionations within either the living things or the man-made artefacts domains, that gave rise to deficits specifically affecting highly limited domains of knowledge have been also frequently described. Therefore, the picture of category specific deficits in patients with neurological diseases different from HSE presents a much higher variability with respect to categorical deficits associated to the herpes type of aetiology.

A series of studies concerning category specific deficits in patients with different types of neurological damage are presented below; the brain areas involved are only briefly described in the following sections (3.2.2 and 3.2.3). However, a more extensive account of the lesion data in HSE and other pathologies will be described later in sections 3.4.1.1. (HSE) and 3.4.1.2 (other aetiologies), in order to draw some general conclusions about the cerebral regions usually affected in patients presenting category specific deficits.

3.2.2 Review of category specific deficits in HSE patients

The best examples of a clear dissociation between the semantic knowledge of living things (defective) and man-made artefacts (spared) have been reported in patients who suffered from herpes simplex encephalitis. However, evidence of different types of fractionations within the semantic memory system were also described along with the living things impairment: knowledge of foods, precious stones, textiles and musical instruments, were frequently reported to be damaged in HSE patients. Quite remarkably, also fractionations within the living things class were sometimes reported after HSE, although this phenomenon is typically observed in relation to other aetiologies. A survey of the most relevant cases of category specific deficits for living things in HSE patients will be presented below (see table 1 for an outline of their general neuropsychological profile and lesion site). The critical dissociation and the theoretical accounts proposed by investigators will be only briefly described. The anatomical data will be only outlined, because they will be more exhaustively presented in a following section (3.4.1.1).

In the seminal work by Warrington and Shallice (1984), four patients (JBR, SBY, KB and ING) were described. In all cases, a predominantly bilateral involvement of temporal lobes was reported. Their assessment was made through the use of a series of tasks, comprising visual and verbal identification-naming tasks (JBR and SBY), word definition and miming responses tasks (JBR), and, in the case of two patients with difficulties in language production (KB and ING), a picture-to-word matching task was devised (also to JBR). All patients showed an advantage for the inanimate objects class, in contrast to a much poorer performance with respect to living things (animals in the majority of tasks) and foods. Furthermore, the modality of presentation, visual vs. verbal, was found to be of comparable difficulty with respect to patients' performance, leading the authors to the conclusion that both semantic systems, a visual and a verbal one, were impaired in the patient group. The relative consistency found in patients' performance with respect to stimulus sets was interpreted as a problem reflecting a degradation of patients' semantic knowledge of selective conceptual categories. Taking into consideration the findings of the opposite dissociation, described by Warrington and McCarthy (1983) in a non-HSE patient, VER, who was more impaired in inanimate objects comprehension with respect to animals, plants and foods, the authors suggest, on lines with Warrington and McCarthy's position, that the identification of inanimate objects would crucially depend on the analysis of functional properties, that are instead not so relevant in the case of living things. The identification of living things and foods should rely more on a system devoted to the analysis of sensory features. In order to ensure that the findings were not attributable to artefactual items selection, stimuli were as far as possible counterbalanced for word frequency, and, in some experiments, also for item familiarity. Despite these factors were taken under control, a category specific impairment was still present in patients' performance, leading the authors to consider these as reliable and robust findings.

As already pointed out in the original work of Warrington and Shallice (1984), the effect of confounding variables on patients' performance need proper investigation, in order to verify the reliability of the categorical deficit shown by patients. However, some authors, as will be more thoroughly described in section 3.3.2 of this chapter, proposed that the category specificity phenomenon is not a genuine deficit, but can be instead accounted in terms of more basic factors. Therefore, in a number of studies the influence on patients' performance of an array of potentially confounding factors, such as word frequency, item familiarity, visual complexity, visual discriminability among others, was investigated. For example, a selective deficit for the living things domain was observed in patient HO (Stewart et al., 1992), who was examined with a wide series of naming tasks and a semantic feature questionnaire. However, once frequency, familiarity and visual complexity were controlled for possible confounding influences, the categorical effect was not significant anymore. Therefore the authors cast doubts on the reliability of selective living things deficits, pointing out that they may be a mere effect of uncontrolled lexical and perceptual factors. Moreover, in a later reassessment of patient JBR (already described by Warrington and Shallice, 1984) Funnell and De Mornay Davies (1996) claimed that the patient showed to maintain the category specific deficit for living things only when items were of low familiarity level; his impairment however, disappeared at higher familiarity levels. Furthermore, the patient's performance was not influenced by visual similarity or visual complexity. However, in recent times Bunn et al. (1998) re-tested patient JBR with a set of coloured photographs, matched across categories for familiarity and visual complexity, and no confounding effects were found which could possibly account for the patient's category specific deficit for living things. Therefore, as will be shown in some other studies presented below in this section, truly category specific deficits were observed even after the close control of confounding variables. It is worth stressing, however, that the importance of taking into account the effects of these factors is essential in all studies of category specificity, in order to exclude any possible alternative account of the deficit.

In various studies of HSE patients, the dissociation between living things (impaired) and man-made artefacts (spared) was reported, providing further support to the original findings of Warrington and Shallice (1984).

Two HSE patients were described by Pietrini et al. (1988). Both patients were assessed through an array of tasks including picture naming and recognition, word-to-picture matching, word definition and naming to description. An impairment involving living things naming was observed in patient RM —whose deficit was therefore considered on the light of an output problem—, while another patient, JV showed a semantic memory loss more prominent in the case of plants. In patients RM and JV a lesion affecting bilaterally the inferior and middle temporal gyri, predominantly localised on the left side was observed. The authors discussed their findings attempting a correlation between neuropsychological deficits and cerebral damage, hypothesising the critical role of the temporal lobes and limbic system in the development of a category specific dissociation for living things.

Two other studies by Wilson and co-workers presented data that provide support to Warrington and Shallice's (1984) theoretical account.

Patient C, a professional musician described by Wilson et al. (1995), was densely amnesic and developed a specific deficit affecting the semantic knowledge of living things after an episode of HSE. The assessment of the patient's semantic knowledge was performed through the adoption of picture naming, categorical fluency and sentence verification tasks. The lesion pattern of patient C was characterised by a massive bilateral involvement of the temporal lobes and the limbic system, which was more marked on the left side.

In a study by Wilson (1997) the comparison of four patients, two of them having an HSE aetiology while the other two sustained a brain injury, was performed, and all showed an advantage for man-made artefacts relative to living things. The two HSE patients, JBR and CW, had a lesion localised bilaterally in the temporal lobes. However, patient CW was also affected in the left infero-posterior frontal lobe and the limbic system was damaged bilaterally. All patients underwent a semantic knowledge assessment performed through the administration of Hodges et al.'s (1992) semantic battery, which comprises picture naming, naming to description, picture sorting, word-to-picture matching and category fluency tasks. Along with the category specific deficit for living things, both HSE patients presented a widespread damage involving both visual and verbal semantics associated to living things. In the author's view, the two HSE patients had a storage damage affecting the living things knowledge, whilst the remaining two patients, who suffered from head injury, were thought to have an impairment in the access to visual semantics.

In contrast to the findings of Wilson (1997), where two HSE patients demonstrated a selective impairment for living things involving both the visual and verbal modalities, a slightly different pattern of results is reported by Sheridan and Humphreys (1993). The authors described a patient, SB, who recovered from an episode of HSE and reported a brain damage affecting the left temporal lobe. Patient SB was defective with respect to animals and foods, although she had not an intact performance also with artefacts. The patient's semantic deficit was probed through the use of an array of tasks, including picture naming, naming to descriptions, word definitions, spoken and written word categorisation, object decision, heads test, size judgements, drawing from memory and finally a test of knowledge of visual and functional information. Despite the categorical deficit for living things, the patient demonstrated to have an intact visual structural knowledge of the stimuli belonging to the affected category. However, she showed a defective verbal (but not visual) semantic knowledge of living things and foods. These findings led the authors to conclude that her deficit was due to a loss of verbal semantic knowledge.

At variance with patient SB, described by Sheridan and Humphreys (1993), who showed an intact structural knowledge of living things, Sartori and Job (1988) described the performance of an HSE patient, Michelangelo, who was thought to have an impairment at the level of structural descriptions. The patient was reported to show a selective deficit affecting the categories of animals, fruits and vegetables in contrast to objects, that were found to be spared. The patient had a brain lesion affecting bilaterally the anterior portions of the temporal lobes; he was assessed with picture naming tasks, naming to description, word definition, word-to-picture matching, semantic attribute verification, animal and object decision, completion of drawings, size judgement and generation of semantic attributes. Since the patient's difficulties were prominent in picture naming tasks and when asked to retrieve visual semantic properties of living things but not of objects, his deficit was referred to damage at the level of structural descriptions. However, the patient showed a categorical deficit in favour of objects relative to animals and vegetables also in a naming to verbal description task. The authors account for the whole series of results and for the findings on the naming to description task hypothesising that Michelangelo's deficit is anyway attributable to an impaired structural descriptions level, because "since the structural description is repository of concepts' visual properties and their spatial relations, and at least for some information it is the unique repository, even some verbal tasks may require the retrieval of information stored in the structural description". Another HSE patient, who presented a bilateral damage to the temporal lobes, was described by Sartori et al. (1993b). The patient had an impaired performance on picture naming, drawing, object decision tasks and on the description of the visual appearance of living things with respect to artefacts. The authors proposed the same explanation for the patient's deficit as that adopted for their previously described patient Michelangelo, that of an impairment to the level of structural descriptions.

A subsequent work can be perhaps considered as an attempt to develop Warrington and Shallice's (1984) theoretical account, along the lines firstly proposed by these authors. In fact, De Renzi and Lucchelli

(1994) described an HSE patient, Felicia, who showed a selective damage to her knowledge of living things; in contrast, she was quite preserved with respect to the man-made artefacts category. The patient's damage involved bilaterally the temporal lobes, being more marked on the antero-medial parts, and affecting particularly the left side. The patient's semantic knowledge was probed with naming from pictures and characteristic sounds, word definition, word-to-picture matching, semantic feature questionnaire and object decision tasks; furthermore, the patient was administered with colour retrieval and drawing from memory tasks. The selective sparing of man-made artefacts was ascribed to the close link between the form and the characteristic function of objects, which should make exemplars of the man-made artefacts class more resistant to damage. In the authors' view, however, these form-function relations do not characterise living things representations, which therefore have to rely more on other properties, such as visual ones. Therefore, the selective deficit for living things observed in this patient was attributed by the authors to an impairment of her visual knowledge, rather than a deficit affecting a categorically organised semantic system.

The critical role of the link between living things and their visual properties was again emphasised by Silveri and Gainotti (1988). The authors described an HSE patient, LA, who showed a category-specific deficit affecting both living things and foods. The patient's lesion affected both the right and left fronto-temporal lobes; however, damage was more prominent on the left side. The patient's category specific deficit was assessed with naming to pictures, picture definition, word-to-picture matching, size judgement and categorical fluency tasks; moreover, a naming to verbal description task was administered to LA, in which definitions emphasised either visuo-perceptual or functional-metaphorical properties of both living things and artefacts. Patient LA's selective deficit for the living things class was found to be highly consistent across tasks, and affected both visual and verbal modalities of presentation, being therefore attributed by the authors to a semantic memory loss. Moreover, LA was more impaired on naming animals from verbal definitions when visual properties were stressed, whereas the patient was much more preserved in the case of metaphorical/functional definitions related to animals. Therefore, LA's category specific deficit was interpreted in terms of a selective breakdown of the visual-semantic system, which hampers the patient's knowledge of categories, such as living things and foods, that depend more critically on fine-grained visual discrimination process than is the case for man-made artefacts. A later reassessment of patient LA (Gainotti and Silveri, 1996) confirmed the findings of the previous investigation

(Silveri and Gainotti (1988), since the patient's selective deficit for living things, foods and musical instruments, particularly prominent when visual knowledge was probed, was still present in contrast with a spared performance with man-made artefacts and body parts. The results still held when the stimulus sets were controlled for the influence of confounding factors such as word frequency. However, the patient's performance was found to be influenced by item familiarity, despite the use of balanced item sets.

The fundamental role of visual properties in category specific deficits for living things was also stressed by Ferreira et al. (1997). The authors described two patients, PR and VG, who showed a selective deficit in naming animals with respect to an unimpaired performance as far as actions and tools were concerned. The medial and inferior parts of the left temporal lobe were found to be damaged in both patients, and a further lesion affecting the inferior region of the right temporal lobe was observed in patient PR. Patients were assessed through a series of tasks, such as naming of pictures, actions and verbal descriptions, word definition, word-to-picture matching and drawing from memory. The selective deficit for animals with respect to both actions and tools, observed in a series of naming tasks, was ascribed to an output deficit. However, a differential influence of visual perceptual characteristics (which were found to be impaired) as respect to sensory-motor properties (unaffected) on the patients' performance with living things was reported. This result led the authors to conclude that in the case of animate kinds a prominent role is played by visual semantic attributes, while the processing of actions and tools relies more upon the sensory-motor modality. Furthermore, in these authors' view their neuropsychological findings are consistent with the lesion pattern found in both patients, thus leading to the conclusion of a prominent role of the infero-temporal regions as far as the processing of living things is concerned, and of the occipito-parietal areas in the case of tools and actions.

In a series of subsequent studies the impairment of visual properties, classically associated to the category specific deficit for living things was challenged by case reports of patients whose categorical deficit was not generally paralleled by a problem with visual feature knowledge. Seven HSE patients were described by Barbarotto et al. (1996): four of them (LF, EA, FI and FA) demonstrated a specific impairment for living entities relative to non-living things, that was assessed only with a picture naming task. The four HSE patients with a category specific difficulty with respect to living things had extensive damage affecting bilaterally the temporo-limbic structures, more prominent on the left side. Additional lesions were observed in the medial and basal regions of both frontal lobes. Unfortunately, since only patients' naming performance was assessed in this study, it was not possible to conclude whether their categorical deficit was attributable to a semantic memory loss or to an output problem. However, in a subsequent study Laiacona et al. (1997) re-tested two HSE patients, LF and EA, who demonstrated, in a previous report by Barbarotto et al. (1996), a selective advantage for artefacts over living things in visual confrontation naming. In the latter study a more wide-ranging assessment of the patients' semantics was performed, with the use of picture naming, word-to-picture matching, property verification, object decision and category fluency tasks. Patients' categorical deficit was shown to affect their performance in a variety of tasks, thus excluding, at least in these two cases, an impairment affecting only the output modality. Furthermore, their deficit was still present after a close control of relevant factors, demonstrating that the dissociation was not artefactual. Moreover, a differential impairment of either sensory or functional-associative properties was not reported, being the two patients equally defective with both types of information. Therefore, in patients LF and EA the categorical impairment of living things was not matched by a differential featural deficit, in contrast to the predictions of Warrington and Shallice's (1984) theoretical account.

A puzzling pattern of findings was presented by Laws et al. (1995) as regards to the relation between categorical and featural knowledge. The authors reported an HSE case, SE, who was assessed through a large series of tasks (picture naming, word definition, sorting by semantic attributes, judgement of size differences, semantic attribute verification). SE damage was localised predominantly in the right temporal lobe. The patient was unable to retrieve functional and associative information in contrast to sensory properties of animals, for which he was better preserved. However, the patient was equally able to name animals and man-made artefacts. However, this striking pattern of impairment was not reported in a later re-assessment of the same case (Moss et al., 1997). In the Moss's investigation, the patient was probed with a large array of tasks, including object decision, item match and minimal feature view of the BORB battery; moreover, picture naming, verbal definition, semantic priming of functional, sensory, superordinate and category relationships, and property verification tasks were administered to patient SE. At variance with Laws and colleagues' findings, these authors described in patient SE a category specific deficit for living things and, more importantly, an impairment affecting the knowledge of their visual attributes, in contrast to a preserved knowledge of visual properties in the case of non living things.

The examination of visual perceptual processing in a patient, MS, who suffered from HSE was also reported by Metha et al. (1992). The patient presented a severe bilateral damage affecting extensively the temporal and occipital lobes. The patient's selective deficit for living things was observed in a visual recognition task and in tasks probing both visual imagery and factual information knowledge. Patient MS was previously described by Young et al. (1989). The patient's selective impairment for living things was probed by Young and colleagues with naming from description, category fluency, category verification and a semantic priming task. MS's deficit for living things was more prominent in the case of low typicality stimuli. Despite his inability, however, the patient showed a dissociation in the categorical knowledge of living things when tested explicitly or implicitly. In fact, he exhibited a reliable priming effect when required to verbally pronounce words that were preceded by their category name, both in the case of living things and man-made artefacts. In the authors' view, this finding highlighted an implicit access to semantic information related to both living and non living things, that however was not consciously available to the patient.

A quite different position in the investigation and explanation of category specific deficits for living things is held by Tyler and co-workers (Tyler and Moss, 1997; Moss et al., 1998a, b), who put forward a novel perspective in the way sensory properties should be considered. The authors investigated an HSE case, RC, who presented the typical deficit for living things (0% with living vs. 46% correct with artefacts in visual confrontation naming; 17% with living vs. 75% correct with artefacts in a word-to-picture matching task). The patient showed a bilateral temporal damage, more prominent on the left side. Despite his categorical deficit, the patient's knowledge of verbs related to biological functions (in later studies called "shared properties", by the authors) was better preserved than that of nouns associated to sensory (distinctive properties, in the authors' terms) information as respect to the living things class, whereas the same effect was not observed for artefacts. The observation in this patient of the categorical deficit on the one hand, and a comprehension of nouns and verbs which was influenced by the same variables (familiarity and distinctiveness) on the other hand, led the authors to conclude that the semantic representation of both properties is "captured by a single distributed semantic system".

Table 1: Outline of the cognitive profile of HSE patients who showed a category specific deficit for living things

Authors	Patients	Naming	Language deficits	Memory Deficits	Visual processing	Lesion site
Warrington & Shallice (1984); Funnell, De Mornay Davies (1996); Wilson, (1997); Bunn et al. (1998)	JBR	×	Mild dyslexia, word comprehension	Severe anterograde and retrograde	×	T bil.
Warrington & Shallice (1984)	SBY	×	Word comprehension	Severe anterograde	×	T bil.
Warrington & Shallice (1984)	KB	×	Global aphasia	Severe anterograde	nr	T bil., >L
Warrington & Shallice (1984)	ING	×	Aphasia, dyslexia, dysgraphia	Severe anterograde	×	T bil.
Ratcliff & Newcombe (1982); Young et al. (1989); Metha et al. (1992)	MS	+	+	Amnesia	×	TO, Toj, parahippocampus
Pietrini et al. (1988)	RM	×	+	Severe anterograde	+	Inf-med T, >L
Pietrini et al. (1988)	JV	×	+	Severe anterograde	+	Inf-med T, >L
Sartori & Job (1988); Sartori et al. (1993a)	Michelangelo	×	+	Severe anterograde	+	T bil., >ant
Silveri & Gainotti (1988) Gainotti & Silveri (1996)	LA	×	Wernicke's aphasia	Severe anterograde and retrograde	nr	FT bil.
Stewart et al. (1992)	HO	×	+	Severe anterograde	+	nr
Sartori et al. (1993b)	Giulietta	×	+	Severe anterograde	+	T bil., hippocampus
Sheridan & Humphreys (1993)	SB	×	Mild dyslexia, mild comprehension	Anterograde, retrograde	+	L T
De Renzi & Lucchelli (1994)	Felicia	×	+	Severe retrograde	+	L F bas., T insular bil.
Barbarotto et al. (1996); Laiacona et al. (1997)	LF	×	Anmestic aphasia	Anterograde, retrograde	nr	L T, insula, hippocampus,; bil parahippocampus; L F med; R T bas
Barbarotto et al. (1996); Laiacona et al. (1997)	EA	×	Fluent aphasia	Anterograde, retrograde	nr	L T, insula, hippocampus, parahippocampus, R T bas
Barbarotto et al. (1996)	FA	×	nr	Anterograde, retrograde nr	nr	L T lat, L F bas-med; R F med
Barbarotto et al. (1996)	FI	×	Anmestic aphasia	Anterograde, retrograde nr	nr	L T, insula, hippocampus, parahippocampus; L F bas
Laws et al. (1995); Moss et al. (1997)	SE	±	+	+	+	R T pole, uncus, hippocampus, parahippocampus, T inf-lat; L: uncus, amigdala
Tyler & Moss (1997); Moss et al. (1998 a, b)	RC	×	Dyslexia	Severe retrograde and anterograde	+	T bil. >L, caudate, hippocampus
Wilson et al. (1995)	C	±	Anomia	Anterograde, retrograde	nr	T bil., limbic bil.
Wilson (1997)	CW	±	Anomia	Anterograde, retrograde	+	T bil., limbic bil., L F inf-post
Ferreira et al. (1997)	PR	±	Anomia	+	+	L T med-inf, R T inf.
	VG	±	Anomia	+	+	L T med-inf.
Young et al. (1989); Metha et al. (1992)	MS	±	+	Amnesia	×	T bil, O bil.

+: good performance; ±: mildly defective performance; ×: impaired performance; nr: data not reported

In conclusion, HSE patients who were reported to show a category specific deficit for living things with respect to the man-made artefacts category (see table 1), usually, although not always, present an impairment that highlights a semantic memory loss observed both in verbal and visual modalities of presentation and affecting both production and comprehension processes. Their deficit for living things, affecting therefore in the majority of the cases the patients' knowledge of animals, fruits and vegetables, is sometimes corresponded by an impairment of foods knowledge, and a similar pattern is also followed by musical instruments. In contrast, patients' knowledge of man-made artefacts is found to be relatively intact or, at least, better preserved than that of living things; a further effect is the observation of the sparing of the knowledge of body parts along that of artefacts.

The categorical deficit for the living things domain is in many instances matched by an impairment of visual semantic properties of the affected category, in contrast to the preservation of functional-associative information. However, a series of studies found some variability as regards to the featural impairment regarding functional and sensory information, sometimes affecting both sorts of semantic attributes, in other instances none of them, and in further cases disrupting the knowledge of specific types of sensory attributes.

The lesion data, although highlighting some variability —possibly due to the temporal gap between the onset of symptoms to the beginning of the treatment, which can influence the extent of the cerebral damage—, generally show a bilateral or a (predominantly) left involvement of temporal lobes, and in a minor number of instances of frontal lobes: both temporal and frontal lobes are often affected in the inferior, medial and basal regions. Along with the damage to the temporal lobe, an involvement of limbic structures is often described. Further damage to other cerebral areas, such as parietal and occipital lobes are also reported, but are far less frequent with respect to the temporal and frontal lesion. Hence, the conjoint examination of categorical impairments and neural correlates in HSE patients with category specific deficits for living things seems to suggest the critical role of the inferior and medial portions of temporal lobes in the semantic processing of the living things category. This issue will be however discussed in more detail in a further section (3.4).

Finally, the artefactual nature of category specific effects can be excluded in the large majority of the cases, whereas it is found to account for the deficit on a very few cases. However, an effect of potentially confounding variables is often found to influence patients' performance. Anyway, an explanation in terms of basic factors has been frequently challenged in further re-assessments of the patients' performance and, more importantly, the category specific phenomenon is generally not accountable just on the basis of the influence of these variables, since other theoretical explanations provide much more exhaustive and reliable accounts. However, this last issue will be more thoroughly discussed in a later section of this chapter (3.3.2).

3.2.3. Review of category specific deficits in patients with other aetiologies

Degenerative diseases

Several cases of patients with a degenerative damage, such as semantic dementia or progressive aphasia, have been described to show category specific deficits either for the living things or the man-made artefacts domains.

A number of reports have been described in the literature, showing a category specific deficit for living things, in contrast to a spared or relatively better performance as far as man-made artefacts were concerned. Cardebat et al. (1996) described a patient, GC, who showed a selective difficulty in naming and word-to-picture matching tasks when stimuli were animals in comparison to objects, where only minimal problems were observed. GC had a cortical atrophy restricted to the left temporal lobe, predominantly in the inferior medial and posterior portions. The patient's semantic knowledge was assessed through the administration of picture naming, category fluency, word-to-picture matching, picture categorisation, definition of objects and a SPECT activation study where the processing of visual attributes of animals and objects was assessed. Interestingly, in the SPECT activation study size judgements about animals were performed by GC poorer than in the case of objects. Furthermore, the presentation of animals was associated to a selective activation of bilateral frontal regions, while objects activated specifically the left posterior-middle temporal areas. The SPECT findings led the authors to suggest that the observed activation of the left temporal lobe in the posterior and middle regions indicates the access to the conceptual knowledge of objects, which are better preserved in patient GC with respect to animals. In the latter case, however, animals did not activated these regions of the temporal lobe, indicating a poor access to semantic knowledge. This lack of activation would therefore reflect the disruption of the neural circuitry critically involved in processing living things, depending on the patient's lesion pattern.

A category specific deficit which presented the typical pattern of deficits hypothesised by Warrington and Shallice (1984) was reported by Basso et al. (1988). The authors described the case of a patient, NV, with a generalised temporal atrophy, more marked in the left temporal areas, who showed an impaired auditory verbal comprehension of animals, fruits and vegetables. The patient was assessed with tasks including picture naming, category fluency, verbal and visual categorisation, feature verification at the category and attribute level, object decision and two tasks involving colour-to-picture and sound-to-picture matching. The patient presented further difficulties in verbal knowledge of perceptual properties of the items he could not understand, in contrast to the selective preservation of the verbal knowledge of functional information. Moreover, he was also impaired in both matching tasks, showing therefore marked problems in tests requiring subtle perceptual (both visual and auditory) processing of the stimuli.

However, in two subsequent studies a selective deficit for living things, along with no differences in attribute knowledge was observed. In fact, a patient reported by Barbarotto et al. (1995) showed a progressive deterioration of comprehension and naming abilities as regards to living things. The patient presented a lesion pattern which affected principally the lateral and basal aspects of the right temporal lobe, the hippocampus and the parahippocampal gyrus. An atrophy of the caudal nucleus was also found, and, in later stages of the illness, also the left temporal structures were found to be involved. An array of tasks was presented to probe the patient's semantics, such as picture naming, word-to-picture matching, object decision and finally a property verification task. The patient was tested in two different sessions, and in a naming task he was poorer with living things than with man-made artefacts; in a word-to-picture matching task the patient's performance improved, but was still defective with living things in contrast to artefacts. In the Laiacona et al.'s (1993b) questionnaire, his deficit for living things was again severe with respect to man-made artefacts. Despite the patient presented a categorical deficit affecting the semantic knowledge of living things, no differences were reported of a differential deficit for visual and non-visual properties as respect to both living things and artefacts in the property verification task.

A selective deficit for living entities was recently reported by Samson et al. (1998), who described a patient with an atrophy in the posterior part of the left hemisphere and hypodensity in the left frontal paramedian areas. The patient's assessment involved a series of tasks including oral and written picture naming, naming to descriptions, object decision, auditory lexical decision, categorisation, size judgements, word-to-picture verification and verbal description. The patient had a selective naming impairment that was shown also when stimuli were controlled for potentially confounding factors. When visual processing was assessed, no deficits of structural levels were observed. Moreover, the patient's knowledge of both visual and non-visual attributes of living things was overall impaired, while in the case of man-made artefacts was found to be spared for both types of properties. Therefore, the authors claim that the findings cannot be accounted for by the hypothesis of a damage to the visual semantic system. Rather, they propose that the patient semantic deficit provides evidence for an interpretation in terms of the categorical organisation of the semantic system into the main domains of living things and man-made artefacts, on the lines of Caramazza and Shelton's (1998) position.

The influence of artefactual effects in category specific deficits for living things was investigated by Parkin (1993). In fact, in a re-analysis of patient TOB, previously described by McCarthy and Warrington (1988), the author observed that the patient's atrophy involved the left perisylvian regions, and was characterised by a significant hypometabolism localised in the three gyri of the left temporal lobe and in the left posterior frontal gyrus. Patient TOB's semantic knowledge was examined through the administration of the whole Snodgrass and Vanderwart's (1980) set of drawings and with a further picture naming task, in which the two sets of living things and artefacts were balanced for potentially confounding factors. Despite an initial selective deficit was found to affect the naming of living things with respect to man-made artefacts, when the set of stimuli matched for all critical factors was used, the patient's categorical deficit disappeared.

In a few studies of patients with degenerative disease, however, the complementary pattern was reported, of an advantage for living things in contrast to man-made artefacts. Patient CG (Silveri et al., 1997) with a probable semantic dementia, had damage in the left inferior parietal lobule and the temporal pole. The patient's conceptual knowledge was tested with picture naming (four sessions), naming to definition, word-to-picture matching and a questionnaire about perceptual and functional attributes of living things and artefacts. The patient was found to have naming abilities that, though the effect was mild, were more defective in the case of inanimate objects than in the case of animate things. In the authors' view, the patient's deficit, which affected only the verbal production process, cannot be therefore considered of semantic nature, since he was completely unaffected in all comprehension tasks, but rather an output problem. Furthermore, in the authors' position the patient's pattern of neurological damage gives support to the hypothesis that a deficit specifically affecting inanimate objects depends on a lesion which affects unilaterally the left temporal lobe; however, a selective impairment for living things is held by the authors to be produced by bilateral damage to the inferior temporal lobes.

In the two further studies presented below, the importance of evaluating a featural deficit along with the categorical deficit was emphasised. A case of generalised cerebral atrophy was reported by Moss and Tyler

(2000). The patient's damage was widespread and patchy, although a substantial lesion could be located bilaterally in the inferior temporal lobes and was more extensive on the right side. The patient's semantics was tested with picture naming, property verification, semantic priming, word definition and naming to descriptions. The naming and recognition skills of the patient were more impaired for artefacts relative to living things, even when the potential influence of confounding factors, such as familiarity and age of acquisition, was partialled out. Furthermore, no evidence of a differential impairment of sensory vs. functional/associative semantic properties was found. The findings led the authors to conclude that a deficit for man-made artefacts may emerge as a consequence of a severe and generalised semantic memory damage, in keeping with the predictions of their connectionist model (Tyler et al., in press).

An interesting pattern of findings was observed by Tyler and Moss (1997), who described three cases of progressive aphasia (PP, AM, and SC). The patient group showed a severe impairment of semantic memory, affecting both the production (patient PP, AM and SC) and the comprehension sides (patients PP and AM), without signs of a selective categorical impairment. Patient PP had damage affecting the left inferior frontal areas and the temporo-parietal regions; patient AM showed an atrophy affecting the temporal lobes, which involved predominantly the inferior and lateral regions, most marked on the left; patient SC was found to have a damage localised in the left temporal lobe. Since patients were generally not able to perform classical tasks such as confrontation naming, sorting and picture pointing tasks, their semantic knowledge was assessed through the use of an implicit task such as semantic priming. The priming task consisted in a lexical decision task based on two sets of prime words, regarding living and non living things. Each prime word was coupled with a functional or a perceptual property. In addition, prime-target pairs were characterised by two different category relation: superordinate and coordinate. Therefore, each prime word was paired with each of the four types of targets (e.g.: crocodile: animal (superordinate); elephant (coordinate); green (sensory); river (functional/associative). All patients showed a generalised impairment of semantic representation with the only exception of the selective preservation of functional information, which remained accessible for both living things and man-made artefacts. The relative sparing of functional/associative information was accounted for by the authors in terms of form-function intercorrelations which are held to exist both for living things and man-made artefacts and to be more resistant to brain damage with respect to other types of semantic attributes.

Vascular damages

Evidences of a dissociation between living things and man-made artefacts categories were also described in patients with vascular damage. In patients with this type of aetiology the amount of variability as respect to both findings and lesion sites is much higher than in the case of the degenerative diseases described above. However, an attempt at describing the most relevant data will be performed below.

A series of case studies, reported in patients who suffered from vascular damage, a category specific deficit affecting the living things class, as respect to an advantage for man-made artefacts.

On the same lines of Warrington and Shallice's (1984) position, an impairment of visual knowledge was held to be the problem affecting a patient (Barry and McHattie, 1995) who suffered from a cerebrovascular accident. Lesion data are unfortunately not reported by the authors. The patient's semantic knowledge was probed with picture naming, word-to-picture verification, word-to-picture matching and with a questionnaire assessing category and perceptual information. The patient presented a naming impairment and a severely defective perceptual knowledge regarding animals; the deficit also remained when confounding factors were controlled. In the authors' view, the poor knowledge of visual attributes of animals might be attributable to a problem in accessing a full representation of animate kinds. Since visual knowledge was much more defective than category knowledge, the authors argue that the patient's category specific deficit might depend on his difficulties with visual features, which are held to be critical in the processing of animate things with respect to artefacts.

An influential study within the category specificity field was presented by Caramazza and Shelton (1998), who reported the case of patient EW, who had a lesion, due to a left cerebral vascular accident, involving the left posterior frontal and parietal lobes. The patient was probed with tasks as picture naming, naming of sounds, feature verification, judgement of general vs. specific attributes and of visible vs. non-visible features and size judgements. An impairment affecting naming, visual and auditory recognition, and the knowledge of both visual and functional attributes of animals was shown by the patient. From the examination of the findings, the authors therefore conclude that category specific deficits depend on the categorical organisation of the semantic memory system. Their position is thus in contrast to Warrington and Shallice's (1984) proposal that, for processing living things and man-made artefacts classes, critical is the differential influence of sensory and functional attributes, a difference that was not found on patient EW's performance.

A different pattern of deficits was instead reported in a subsequent study, describing a patient whose impairment was not affecting his semantic knowledge of living things, but was rather attributable to a problem in earlier stages of the visual processing: Forde et al. (1997) described the selective impairment for living things in a patient, SRB with a damage to the left infero-medial regions of the temporal lobe, involving also the occipital lobe and a small portion of the thalamus. Patient SRB was assessed with a large series of tasks, among them numerous naming tasks with different modalities of presentation, naming to descriptions, word definition, and various tasks tapping the visual recognition of stimuli, and, in particular, the knowledge of their associated colours. Furthermore, the patient was required to perform perceptual judgements, size matching and drawing from memory tasks. The patient was defective in naming living things across several modalities and when descriptions emphasising visual properties were used. Moreover, the patient showed a category specific deficit for the living things class also in naming the colours of the affected category, in drawing from memory and in perceptual comparisons. However, the patient's performance in semantic tasks was relatively spared. Therefore, the authors explained the deficit in terms of a specific difficulty in processing stimuli which require subtle perceptual discriminations.

In two subsequent studies category specific deficits for living things were described as being a consequence of a lexical output problem. A patient, MD, with a lesion to the left frontal lobe and basal ganglia was reported by Hart et al. (1985). The patient's assessment was performed with tasks such as oral and written picture naming, naming to descriptions, sorting of pictures into categories, word-to-picture matching, category fluency, perceptual judgements and categorisation of written words. The patient showed naming difficulties with respect to fruits and vegetables, while his ability to name artefacts and foods remained intact. However, his comprehension was generally spared, except in the semantic categorisation task. The authors conclude that the lexical-semantic system is categorically organised, in particular at the input and output levels to and from this system; furthermore, the phonological output lexicon is addressed by categorical semantic information, which can be selectively disrupted. In the authors' view, the patient's deficit is therefore not due to a semantic memory loss, but to an output problem. A deficit affecting more severely naming abilities as regards to fruits and vegetables, and in a milder form animals, plants and insects, with respect to a good performance with inanimate semantic categories, was described by Farah and Wallace (1992) in a patient who had a lesion localised in the left occipital lobe. The assessment was based on an array of tasks, including a series of picture naming, naming to description, category fluency, word definitions, word-to-picture matching and cued naming; the majority of these tasks involved specifically fruits and vegetables. The patient's naming deficit for fruits and vegetables involved both visual and verbal modalities. However, in contrast to the poor naming performance, the patient had a much more preserved knowledge of the semantic categories he was unable to name. Moreover, the patient performed very well in a word definition task involving both fruits and vegetables. The pattern of findings led the authors to exclude a semantic memory deficit, favouring an interpretation in terms of a lexical output problem. Furthermore, the increased performance in phonemic cueing naming condition shown by the patient, led the authors to conclude that the patient's impairment was not at a phonological level. Hence, the authors accounted for the patient's overall performance in terms of a computational model in which hidden units between semantic and phonological layers were damaged.

A further series of studies provided evidence of the opposite pattern of impairments and preservation in category specific deficit. A series of researches highlighting a selective advantage for living things in contrast to a relatively defective performance as respect to man-made artefacts will be then described.

Two influential studies within the category specificity field were presented by Warrington and McCarthy (1983; 1987): In the first study, the authors reported the case of patient VER, who showed an advantage for living things over man-made artefacts. The patient had a severe left hemisphere infarction and showed damage localised in the left fronto-parietal areas. The patient was examined using matching-to-sample tasks and was shown to have a better performance in the case of animals and flowers than with objects; a differential performance was also observed when foods (preserved) and objects (impaired) were probed with the same paradigm. The patient's impairment was ascribed to an access problem to semantic representations of objects. In a subsequent work (Warrington and McCarthy, 1987), the authors described patient YOT, who suffered from left middle cerebral artery occlusion that led to a cerebral lesion affecting the left temporo-parietal regions. The patient underwent the administration of visual and verbal naming, visual-visual matching, spoken-to-written word matching, spoken word-to-picture matching and pointing tasks. Patient YOT could not name and comprehend both through visual and verbal modalities inanimate stimuli with respect to living things and foods, and she showed a greater loss in the case of small manipulable objects with respect to large non-manipulable objects. In the authors' opinion, the deficit related to small manipulable objects shown by patient YOT cannot be explained by an account of category specific deficits crucially based on the influence of functional vs. sensory properties, differentially involved in the processing of man-made artefacts vs. living things respectively (Warrington and Shallice, 1984). The authors suggest instead that fine-grained fractionations within a semantic domain, such as the one described in this patient, might be better explained taking into account the contribution of differing weighting values for semantic information depending on sensory/motor modalities and on specialised channels (for peculiar semantic attributes, for example colour or texture in the case of a sensory channel) within each modality.

A position that clearly contrast to the theoretical account of category specificity given by Warrington and Shallice (1984) was put forward by Hillis and Caramazza (1991). The authors described patient JJ, who suffered from a thrombo-embolic stroke, and as a consequence had damage to the left temporal lobe and basal ganglia on the left side. Patient JJ was administered with seven subsequent sessions of a picture naming of ten different categories, and with spoken and written word-to-picture matching tasks. The patient showed a semantic memory deficit for non-living things, while knowledge of animals was found to be spared: his deficit was accounted for in terms of a semantic memory impairment which highlights the categorical organisation of lexical-semantic knowledge. On the same theoretical framework is interpreted the case of a patient, KE, reported by Hillis et al. (1990), who showed a lesion area comprising the left fronto-parietal regions. The patient was examined through different modalities and with a wide array of tasks, such as picture naming and spoken and written word-to-picture verification across different semantic categories. KE's errors shown in naming, reading, writing and comprehension, were examined, and the patient's performance was found to be poorer for non living categories than in the case of living entities across modalities.

At variance with previous theoretical accounts, an access problem was held to be the locus of impairment of a patient who showed a category specific deficit for inanimate objects (Sacchett and Humphreys, 1992). The authors assessed the patient's semantic knowledge with picture naming and picture-to-word matching. Naming skills regarding inanimate kinds and body parts were found to be severely disrupted relative to living things in patient CW, who suffered from a left fronto-parietal infarct. However, in a picture-to-word matching task the patient showed a milder deficit, being at ceiling with living things, but showing a dramatic improvement also with man-made artefacts and body parts with respect to the naming task. The authors argued that his problem could be ascribed to a defective access to an intact semantic knowledge from the visual modality of presentation.

A quite complex pattern of findings was reported by Coltheart et al. (1998), that led the authors to propose a novel fractionation within the semantic memory system as respect to different modalities of input. The authors described patient AC's performance, who suffered from a stroke that affected the surrounding territory of the left middle cerebral artery, with further patchy lesions and signs of leucoarayosis throughout both hemispheres. The patient assessment comprised, among them, picture naming, copying and drawing, gesturing object use, perceptual and non-perceptual feature verification, picture-to-word matching, minimal features and foreshortened view tests of the BORB battery, picture-to-colour and word-to-colour matching. The patient showed a specific deficit affecting only the retrieval of visual semantic properties, with no impairments to other perceptual modalities or non-perceptual knowledge, regardless of the semantic category probed. The authors' proposal is that of a fractionation of semantic memory system into specialised subsystems devoted to the processing of distinct perceptual modalities; a further subsystem, committed to non-perceptual knowledge, is then held to be categorically organised.

Finally, the case of a patient with a category specific deficit limited to the lexical retrieval was described by Cappa et al. (1998a). A category specific deficit affecting selectively the ability to name tools, and, to a less severe extent, furniture, was observed in patient GP, who suffered from an haemorrhage affecting in particular the anterior part of the left temporal lobe, including the left temporal pole. The patient's assessment involved oral and written picture naming, naming to descriptions, word-to-picture matching, word-to-picture verification and a semantic verification task tapping superordinate, perceptual and functional-associative information, both in the verbal and visual modality. The categorical effect found in patient GP's naming was not influenced by modality of presentation, word frequency, familiarity and other relevant lexical factors (word length, grammatical class. In contrast to the patient's naming impairment, both GP's performance in the matching task and his semantic knowledge of the items he was unable to name were generally well preserved. The authors stress the prominent role of the anterior parts of the left temporal lobe in lexical retrieval processes, casting doubts on the involvement of some of the cerebral areas (left temporal pole) as predicted by the anatomical model of lexical retrieval proposed by Damasio et al. (1996).

Head injuries and other pathologies

A series of studies of patients who, after a brain injury, developed a category specific deficit for living things is now presented. It has to be observed that none of the cases described showed a categorical deficit selectively affecting the man-made artefacts class.

A first group of researches emphasised theoretical accounts that, in general, suggest an organisation in terms of multiple components within the semantic system. A selective deficit affecting the naming of living things was described by Hart and Gordon (1992) in a paraneoplastic patient, who showed a diffuse lesion including bilaterally the temporal lobes. The patient's semantic abilities were tested through the use of tasks such as oral and written picture naming, non-verbal sounds naming, perceptual and non-perceptual feature judgement and finally naming, matching and pointing animal parts. The patient's categorical naming deficit was also paralleled by an impairment affecting both the verbal and visual knowledge of animate kinds. From the findings reported, the authors support the view of a semantic system organised both in terms of modality and semantic property types.

An interesting case study was described by Powell and Davidoff (1995); their patient had a bilateral atrophy of the occipital poles and hypodensity in the anterior parietal sub-cortex of the right hemisphere; the left hemisphere, although not normal, was more spared than the right one. The patient was tested through a series of "overt" tasks, such as "legs test" and attribute verification, and with an implicit task, tapping the patient's ability to recall paired words, related to both categorical knowledge (animate vs. inanimate) and attribute knowledge (visual vs. functional/associative). In the attribute verification task, the patient showed an unimpaired knowledge of functional/associative properties of animate kinds; in contrast, her visual knowledge of animate entities and her functional/associative knowledge of inanimate objects were damaged. Furthermore, in the paired-word recall test, visual information associated to both animate and inanimate things could not be retrieved and learnt as good as in the case of functional/associative knowledge related to both semantic domains. The authors suggested that the hypothesis of a multiple-store model of the semantic memory system, organised in terms of both category and attribute knowledge, is supported by their findings.

In a further investigation, Farah et al. (1989) described a patient, LH, who showed a selective loss of visual information about animals, plants and foods after head injury that caused bilateral lesions in the temporo-occipital areas and in the right inferior frontal lobe. The patient was tested with a series of tasks, including picture naming and a test of visual/functional knowledge about living and non living things. Patient LH had a poor performance when visual properties of living things was probed, but was normal with respect to both visual knowledge associated to artefacts and functional information about both living things and man-made artefacts. In the authors' view, LH's deficit might depend on an underlying difficulty affecting a distinct subsystem devoted to visual knowledge related to the living things category. Therefore, the authors propose that the semantic system is organised in terms of both category and modality.

However, a further paper examines evidence of the independence of attribute knowledge from categorical knowledge in patients with category specific deficits. Laiacona et al. (1993a) described the selective disruption of the knowledge of living things in two patients (FM and RG), who had suffered from brain injury. Patient FM had lesions in the left posterior parietal areas; furthermore, the patient showed a cortical deep atrophy, highlighting an involvement of frontal lobes bilaterally, and of the left temporal lobe. Patient RG showed diffuse compromising of the left hemisphere, specifically involving the left frontal and left posterior temporal parts. Both patients were probed with picture naming, word-to-picture matching tasks and with a semantic feature questionnaire. Both patients showed an equal performance with respect to functional/associative and perceptual properties in the semantic questionnaire. The categorical effect remained also when the influence of unbalanced factors was controlled.

A quite different theoretical perspective is held in two subsequent studies, that provide evidence in favour of the hypothesis that the semantic system is organised categorically. Patient PS, described by Hillis and Caramazza (1991), who showed a selective deficit for animals and vegetables with respect to other semantic categories, had a damage to both temporal lobes and to the left frontal lobe after brain injury. The patient's conceptual knowledge was examined through a picture naming of ten semantic categories and the spoken and written versions of a word-to-picture matching task. The patient showed a selective categorical deficit for animals and vegetables over seven sessions of a naming tasks. Despite the patient's deficit in the naming tasks, his performance in other tests was remarkably better. In a spoken word-to-picture matching task PS was virtually unimpaired with animals, vegetables and other categories. Furthermore, in a written word-to-picture matching task his performance was good and quite comparable across categories. Taking into account these data along with those of patient JJ, described in the same paper, the authors suggested that these evidences provide support to the categorical organisation of the lexical semantic system.

In two papers, attention was devoted to the assessment of the influence of confounding factors and methodological errors which can affect the performance of patients with category specific deficits. The performance of two patients with closed brain injury was described by Farah et al. (1991): patient LH, already described in Farah et al. (1989), presented extensive damage involving bilaterally the inferior temporo-occipital lobes and the right temporal and frontal lobes; the other patient, MB, had a lesion affecting the left temporal lobe. Patients were assessed through a visual confrontation naming task comprising the whole Snodgrass and Vanderwart (1980) set, and both showed an advantage in naming man-made artefacts over living things stimuli. The specific purpose of this study was that of examining the role of visual complexity, inter-item similarity and other factors —such as item familiarity, word frequency and name agreement—, in the patient's visual recognition of the living things category. However, in both patients it was shown that their category specific deficits still held when these relevant factors were taken into account. In the authors' opinion, patients' locus of impairment was either in the visual system or in the semantic memory system. However, since only a visual confrontation naming task was administered to both patients by the examiners, in this study it was not possible to verify whether the deficit was of agnosic or semantic (modality specific) nature, at least in the case of patient MB, since LH was thought to have an impairment in the visual semantic subsystem, as reported in a previous investigation (Farah et al., 1989).

In a further study of patients MB and LH (both already described in Farah et al., 1991, and Farah et al., 1989, in LH's case), both patients were assessed with the administration of a naming task, where pictures were highly matched for potentially confounding variables (Farah et al., 1996). Both MB and LH did not show a category specific deficit for living things relative to man-made artefacts, with no difference between the two semantic domains. However, with multiple administrations of the same test, they had a reliably and significantly poorer performance in naming living things as respect to artefacts. Therefore, the authors exclude that category specific deficits might emerge as a simple consequence of unbalanced variables, rather, this lack of categorical effect might depend on the lack of statistical power which characterises small sets of items even though balanced for relevant factors. Therefore, the use of repeated administrations of a task might be of help in ascertaining a category specific effect.

In this section, category specific deficits for either the category of living things or man-made artefacts shown by patients with aetiologies different from herpes simplex encephalitis have been briefly described. This phenomenon may emerge from a variety of pathologies, such as degenerative disease, vascular damage, brain injury and other neurological illnesses.

At variance with the quite regular profile of categorical impairment observed in HSE patients, a much varied pattern of categorical deficits arises in patients suffering from other kinds of pathology, often highlighting fractionations within a semantic category that were not so frequently observed in HSE patients (section 3.2.2). However, some conclusions can be drawn from the findings presented above. In the majority of cases, a deficit selectively affecting living things, either the main domain as a whole, or some of their subcategories, has been reported. Category specific deficits for the broad class of man-made artefacts or some more restricted inanimate subcategories, instead, have been described in a minority of investigations. A further consideration has to be made as respect to the observation, in a very few cases, of category specific deficits not involving the semantic memory system as a whole, but rather the lexical retrieval of a class of concepts.

As was observed with respect to the herpes type of category specificity, impairments affecting semantic attribute knowledge associated to the disrupted category have been reported also in patients who suffered from other kinds of aetiologies. An impairment affecting sensory relative to functional knowledge was reported more frequently than the reverse pattern, particularly in association to category specific deficits for living things. However, in about half of the cases described in this section, no difference was observed as respect to the selective sparing or impairment of functional vs. sensory properties knowledge, either in the case of category specific deficits for living things or man-made artefacts. Moreover, in a minority of the studies a specific impairment only affecting attribute knowledge have been reported.

The examination of the lesion pattern more frequently associated to category specific deficit for living things knowledge highlights the critical involvement of the left or both temporal lobes: the cerebral regions more specifically involved have been found to be the inferior and medial portions of temporal lobes. Damage of the right temporal lobe alone, however, has been described with minor frequency. The lesion to temporal lobes is often associated to an involvement of one or both frontal lobes, particularly in the inferior and paramedian areas. In a minority of the studies, other lesions were reported to affect the temporo-occipital areas and the parietal lobes. As far as a selective compromising of man-made artefacts knowledge is concerned, damage almost always involved the left hemisphere, with impairment of temporal, fronto-parietal, or temporo-parietal regions.

A final consideration concerns the studies that directly addressed the issue of artefactual effects in category specific deficits: the large majority of the studies found that even when potentially confounding factors were partialled out, the categorical deficit was still present. In just one study (Parkin, 1993) a category specific deficit for living things disappeared when confounding factors were taken under control. Therefore, as was previously observed in the case of HSE patients in section 3.2.2, despite the obvious importance of controlling for artefactual effects, category specific deficits, either for living things or man-made artefacts, have been shown to be quite robust findings even in non-herpes patients suffering from a variety of different pathologies.

3.3 Theoretical explanations of category specificity

3.3.1 The original account of category specific deficits

In 1984 Warrington and Shallice described a group of four patients who had suffered from herpes simplex encephalitis. All the patients presented with predominantly bitemporal damage. All were global amnesics and had comprehension problems in both the verbal and the visual domains, but they differed in their level of global impairment and in their oral production functions; two (JBR and SBY) had virtually spared speech with the other two showing a grave deficit.

Despite these differences, all the patients showed a qualitatively equivalent pattern of performance in experimental tasks, which aimed at exploring their ability to identify man-made artefacts, living things and food, both in the visual and the verbal modality. Different types of tasks were used to assess the patients' performance: picture-word matching (in all four) and naming, oral description, and miming responses in JBR and SBY. The ability to identify man-made artefacts was relatively preserved in all four patients, but they all showed gross deficits when required to identify living things and foods. The same pattern of relatively intact and defective knowledge was observed both when stimuli were presented visually and when spoken word comprehension tasks were used. Over the last fifteen years a considerable number of patients with herpes simplex encephalitis have been investigated who show a similar pattern (see Barbarotto et al., 1996; De Renzi and Lucchelli, 1994; Gainotti and Silveri, 1996; Laiacona et al., 1997; Sartori and Job, 1988, Sartori et al., 1993 a, b).

The original authors presented evidence that the category specific effect found in their group of patients could not be attributed to other cognitive deficits such as amnesia, word finding difficulties, or visual perception deficits, and, more specifically, that effects of word frequency and picture familiarity could not account for the observed pattern of performance. Warrington and Shallice suggested that category specific effects could be explained by different types of representations within the semantic system for living things (and foods) as opposed to man-made artefacts (inanimate objects, as called in the paper). They proposed that the identification of foods and living things depends critically on the determination of sensory features, which are required in order to make a distinction between exemplars of a given category (e.g. in order to distinguish a horse from a zebra it is important to evaluate the colour and texture of their coats, but their "functions" are irrelevant); on the contrary, the identification of man-made artefacts is based on a fine specification of the function of a given item, while its sensorial attributes are not of basic importance for making a distinction between objects (e.g. a cup and a jug have rather similar and rather variable sensory features, but must each fulfil its different function). Therefore, the semantic representations of living things and man-made artefacts "...would presumably have different patterns of associative links with other cognitive systems ...and with other sensory modalities" (Warrington and Shallice, 1984).

Major support for this view was provided by the cases VER and YOT reported by Warrington and McCarthy (1983, 1987); these patients became global dysphasic after an infarction involving the left hemisphere. In a spoken-word/object matching task they could comprehend, on auditory presentation, names of flowers and animals significantly better than names of objects. This pattern of results provides a double dissociation with the categorical effects described by Warrington and Shallice (1984). This means that an interpretation of the pair of deficits in terms of greater task difficulty of living things or of the differential sensitivity to damage of specific categories of concepts, is made much less plausible (see Shallice, 1988). Further evidences of selective impairment to the artefacts class are reported by Sacchett and Humphreys (1992); a comparable deficit was described on patients with a generalised cerebral atrophy (Moss and Tyler, 1997; Lambon-Ralph et al., 1998, patient IW), progressive aphasia (Moss, Tyler and Devlin, 1999) and after cerebro-vascular accident (Hillis and Caramazza, 1991, patient JJ).

The theoretical position presented from lesion data by Warrington and Shallice (1984) and Warrington and McCarthy (1983; 1987) was corroborated by the findings observed from simulations by Farah and McClelland (1991). In their parallel distributed processing model, the authors assume that semantic knowledge is separated in terms of modalities into two components, a visual and a functional component. Living things are thought to be much more dependent on visual features than functional, whilst a prominent role is held by functional features relative to visual ones in artefacts representation. Then the damage to one component should affect the category whose representations are mostly dependent on that component. However, since the activation of a "critical mass" of units is essential for the access to a given representation, after a severe lesion to one component, the system might be no longer able to access information stored in the relatively unaffected component. Therefore, a damage to the visual component will give rise to a deficit to the living things category and to an impairment of the retrieval of visual properties of living things; a deficit, although not of equivalent gravity, will also affect the retrieval of functional characteristics of the living things category. The reverse pattern, that of a lesion to the functional component should lead to a selective damage to the man-made artefacts class. Moreover, the disruption of the visual features component should cause in the man-made artefacts category a less dramatic deficit relative to that affecting living things, since artefacts representation can at least partially rely on the processing of functional properties, which are still intact. However, it must be stressed that in this computational model the deficit affecting living things still tends to affect the knowledge of visual attributes more than the knowledge of functional information.

On the quite different ground of developmental research, some interesting suggestions are in keeping with the original Warrington and Shallice's (1984) position. In a developmental study (Akiyama and Wilcox, 1993), children's naming abilities were assessed in order to ascertain whether they relay on linguistic information (i.e. mass-count syntactic distinction) or on category information (i.e. objects vs. substances semantic distinction) when they are required to deal with substances and objects. In a first task, the authors used a "grinder" test, to verify if items that undergo transformation maintain or not their identity in children's judgement: a series of substances and objects were presented in their initial form and named to children; after that, items were transformed with the grinder. Items comprised pairs of (i) amorphous substances and discrete objects (e.g. water-a cup); (ii) perceptually similar discrete objects (e.g. chalk- a crayon); (iii) foods (e.g. corn-a bean). The children's task was to decide whether the same name (that could be a count or mass name, from a syntactic point of view) could still be used for the same item after transformation. In this task the authors observed that 3 to 6 year-old children agreed to use the same name in the case of substances, regardless the syntactic cues that were given them in the initial presentation of the item. However, they respected the syntactical constraints in the case of objects. In a further experiment items belonging to substances and unfamiliar hardware were labelled respectively with non-sense mass and count names. The item sets were again presented to children along with the non-sense name and then transformed. In this experimental condition children aged 5 to 8 years, accepted the initial name for transformed substances, therefore relying on conceptual (perceptual!) information rather than linguistic cues, while the same was not reported for unfamiliar objects. These findings led the authors to suggest that children rely on conceptual-semantic information when they have to decide about the maintenance of identity in the case of substances, thus ignoring linguistic cues, while they use linguistic-syntactical information to perform the task when objects are concerned.

A further insight about the type of perceptual information very young children use to deal with mass and count nouns in a period when they cannot yet rely on syntax is given by Soja et al. (1991). In a word-learning task, where unfamiliar objects and non-solid substances were used, two year-old children tend to rely on shape when they have to assign a new name to objects, whereas shape information is ignored in the case of substances. A direct implication of this study is that shape might be relevant in the processing of objects, as it will be discussed below, while other perceptual properties are much more involved in substance analysis. These results seem to provide, from a very different field of research, a direct support to Warrington and Shallice's (1994) view of the fundamental role of perceptual dimensions in processing "sensory-quality" categories, such as living things and, much closer to the present work, "mass" items.

3.3.2 Explanations in terms of more basic factors

Over the last ten years, it has been argued by various investigators that the sparing of man-made artefacts in conjunction with a deficit concerning living things can arise as an effect of the confounding influence of various factors affecting the performance of patients when faced with this type of stimuli.

The first criticism of the original category specific account was put forward by Funnell and Sheridan (1992): in studying patient SL, who was not a herpes encephalitic patient, but who had developed an apparent mild effect of category specificity after a road accident, they showed that their patient's performance, in tasks of naming of living things and man-made artefacts on visual confrontation, could be accounted for in terms of a difference in the familiarity of the items within each category. Specifically, the authors found no effect of semantic category (i.e. living things and man-made artefacts) while familiarity ratings could predict their patient's performance. However, as will be discussed below in this section, their basic effect was found to be not significant in subsequent studies. Furthermore, taking into account the full set of pictures proposed by Snodgrass and Vanderwart (1980), they pointed out that familiarity ratings for living things were generally lower than for man-made artefacts. On the same lines, Capitani et al. (1994) found that a living things disadvantage, observed in a group of 60 healthy elderly subjects when assessed though a semantic knowledge questionnaire, although not explainable by discrepancies in item frequency, familiarity or prototypicality, could be predicted by the relatively higher difficulty of questions related to living things.

However, Funnell and Sheridan did not match the magnitude of the category specificity effect in their patient to any of those studied by Warrington and Shallice. More critically, the deficit observed by Warrington and Shallice had remained when familiarity was removed as a covariate. The Funnell and Sheridan critique was not therefore a powerful one.

In a later paper, Funnell and De Mornay Davies (1996) reassessed case JBR. They still found a category-specific deficit although they argued it was restricted to lower familiarity items, while visual complexity and visual similarity were not good predictors of his performance. However, they also asked a group of normal controls of same sex and comparable age and intellectual performance as JBR to rate the level of familiarity of the item set used to assess JBR's performance, and to name the same set of stimuli. They found that control subjects named more man-made artefacts than living things at every level of familiarity; this observation seems to indicate some greater difficulty in naming living things, even though the stimuli are rated at the same familiarity level as man-made artefacts. Therefore they claimed that the familiarity ratings given by the control subjects would not entirely predict the categorical differences in the performance of subjects on a naming task. On this line of argument JBR's dissociation might instead have an artefactual basis. However, a further investigation of JBR by Bunn et al. (1998) using carefully matched stimuli supported the original findings.

At roughly the same time as Funnell and Sheridan's critique, a related line of criticism was presented by Stewart et al. (1992; see also Parkin and Stewart, 1993). They studied a patient who showed a category specific naming deficit after suffering from herpes simplex encephalitis. In the critical tasks, the patient's performance in naming living things was relatively defective compared to naming objects; however, when the patient was presented with a set of stimuli (used both in naming to visual confrontation and after definition) which were counterbalanced at the same time for word frequency, concept familiarity and visual complexity, all evidence of category specific effects disappeared. However later analysis both of another herpes patient (Michelangelo) of Sartori and Job (1988; Sartori et al., 1993a), using appropriately matched pairs of stimuli, and by Shallice and Cinan (see Shallice, 1996) of patient JBR using multiple regression techniques, showed that in patients with stronger category specific effects, the effects could not be reduced to these three potentially confounding factors. On the same lines, other studies demonstrated how, when the factors outlined to be relevant by Stewart et al. (1992) and Funnell and Sheridan (1992) are controlled, category specific deficit for living things still hold (Farah, McMullen and Meyer, 1991; Kurbat, 1997; Hart and Gordon, 1992; Sheridan and Humphreys, 1993; Laiacona et al., 1993a). In particular, Farah et al. (1996) demonstrated that the lack of effect found by both Funnell and Sheridan (1992) and Stewart et al. (1992) seems to be attributable to (1) the small item set adopted in these studies and (2) the fact that a singular administration of the stimulus set was presented to patients. Using the same two sets of stimuli as in Funnell and Sheridan on repeated assessments of two patients, Farah et al. (1996) found that a category specific deficit did not emerge after the first administration, but highly significant and reliable effects arose when repeated presentation of the same item sets were performed.

Yet a fourth factor that might be the basis for an artefactual explanation was put forward by Gaffan and Heywood (1993). They stressed the role of the visual discriminability of the stimuli within their respective categories, as the source for the dissociation between living things and objects. These researchers observed that, when items have many visually similar neighbours, naming latencies are slowed in normal adults. Moreover normal monkeys have more difficulty in learning to discriminate between such stimuli. Gaffan and Heywood pointed out that exemplars belonging to living things categories have more visually similar neighbours than items belonging to categories of man-made artefacts. They then argued that their results on monkeys "are contrary to Warrington and Shallice's conjecture…that a specific system for identification of man-made objects has evolved in the human brain; if Warrington and Shallice's conjecture were correct then monkeys should show relatively greater difficulty in discriminating among man-made artefacts than living things, compared to human observers". On their argument what is critical for all of monkeys, normal humans and patients is raw discriminability within the relevant category. If however discriminability were the key factor for both the monkey and the patients' performance, then one would expect a positive correlation between the monkey results and the patient results for each of the living and the non-living set of stimuli. In fact, there was no correlation between the stimuli the monkeys found hard and those patients did for either of the two types of stimuli. In addition, Shallice and Cinan (see Shallice, 1996) asked their subjects to rate the relative discriminability of each item from the foils used in a re-analysis of the forced-choice matching results of Warrington and Shallice. No effect of this variable was found. Furthermore, a re-analysis of two patients' performance on the light of Gaffan and Heywood (1993) argument, based on a simulation, showed that the categorical effect found in these patients cannot be accounted in the authors' terms of a lesser discriminability of the living things class combined with measures of errors in normal subjects' performance (Kurbat and Farah, 1998).

Thus none of the accounts which attempt to reduce the deficit in the identification of living things to an effect of a combination of more basic dimensions is convincing. Moreover, none can explain the complementary pattern which has been observed more rarely following temporo-parietal lesions (see Warrington and McCarthy, 1987), fronto-parietal lesions (Warrington and McCarthy, 1983; Sacchett and Humphreys, 1992), and also brain damages localised in other areas (Moss and Tyler, 1997; Moss et al., 1999; Lambon-Ralph et al., 1998; Hillis and Caramazza, 1991).

Despite the variety of positions presented to explain away category specific effects in terms of more basic concepts, the major value of the above mentioned studies consists in stressing the importance of the control of possibly confounding variables, which they clearly demonstrated can influence findings in investigations of semantic memory deficits.

3.3.3 Alternative more complex explanations

The frequent observation of category specific effects has led to a number of theoretical explanations which challenge the hypothesis of the different types of processes involved in the identification of living and man-made artefacts, relying, respectively, on either sensory or functional attributes.

The reports of fractionations within both semantic domains, which were not predicted by Warrington and Shallice's (1984) theoretical view of category specific deficits led some authors to cast doubts on the original account of the deficit. In fact, even though some reported fractionations, such as an impairment affecting musical instruments, textiles and precious stones, and a selective preservation of body parts knowledge described in patient JBR, can be still easily accounted in terms of the sensory/functional distinction, other evidences of further fractionations within the living things category are less easily explained on this theoretical framework. For example, a selective preservation restricted to naming animals was reported by Hillis and Caramazza (1991) in their patient JJ, and another patient was described (Hart, Berndt and Caramazza, 1985, patient MD) who showed instead a selective deficit in fruits and vegetables visual identification.

Therefore, a first attempt to redefine the sensory/functional distinction was made by Warrington and McCarthy (1987): the authors stated that category specific deficits may depend "not only as a consequence of different weighting values between information from each of the major sensory/motor modalities, but also as a consequence of different weighting values on more specialised channels within each modality". Therefore, within each modality specialised channels, for, say, colour, shape, motion, location, might be involved in the processing of very distinct aspects of stimuli: an impairment selectively damaging one of these specialised channels might allow the types of fractionations described above to arise. However, Warrington and McCarthy's (1987) view was criticised by Caramazza et al. (1994), who stated that selective impairments to a specific channel are not sufficient to explain deficits involving for example vegetables, but not animals and vehicles, as in patient JJ (Hillis and Caramazza, 1991). However, this argument do not critically challenge Warrington and McCarthy's (1987) position, since finer examination of the channels which may be damaged or preserved in JJ, as the motion channel, might still explain the pattern of impairment shown by the patient.

A different account of category specific deficits was presented by Humphreys, Riddoch and Quinlan (1988) with the proposal of a Cascade model of picture identification, in which different levels of representation are held to be involved in the emergence of specific deficits for living things and man-made artefacts. In the authors' view, category specific deficits may arise from damage to either one of the components of the model, such as a visual-perceptual discrimination level (Riddoch and Humphreys, 1987a), a structural descriptions stage (Sartori and Job, 1988), an amodal semantic system (Sheridan and Humphreys, 1993), a lexical representation of the object's name (Farah and Wallace, 1992, quoted by Humphreys et al., 1995), or by a deficit in the mapping process from the structural descriptions and the amodal semantic system (Riddoch and Humphreys, 1987b). In the model, activation is held to be transmitted continuously between different levels of representation. The authors state that living things identification in brain damaged patients might be more impaired because of the density of perceptual neighbours, so that living things are more sensitive to competition at each level of representation. In a subsequent work, Humphreys et al. (1995) proposed an interactive activation and competition (IAC) model that was based on the same assumptions of the Cascade model. Three groups of units, corresponding to different stages of the object processing were proposed: structural, semantic and name units. Furthermore, a fourth set of units was added to the model, corresponding to superordinate names.

The authors did not make strong assumptions regarding the nature of representations stored in each pool of units, which were held to be local rather than distributed. Inhibitory links are held to characterise units within a group, while between different pools excitatory bi-directional connections are present. Within the model, the different types of unit are arranged in sequence, and the activation process propagates from structural units, which are held to receive the external input, to the semantic pool; from these units, activation propagates then to name and superordinate units (see figure 1).

The authors hypothesised that the internal representation of living things and man-made artefacts are both of perceptual and semantic nature: the difference between the two categories lies in the fact that living things tend to have a higher level of overlap between exemplars (high level of structural similarity), whilst artefacts are characterised by a low-level of perceptual overlapping (low level of perceptual similarity). Therefore, two main factors were held to modulate the model's behaviour: visual similarity, and word frequency, that were thought to influence respectively the connections between external input and structural units, and the connections between semantic and name units. In order to simulate brain damaged patients' performance, the model was "lesioned" by adding random noise both to the input values and the weights of connections within different components of the model. The model's behaviour was then examined on a series of tasks, namely, object decision, superordinate classification and naming and it was demonstrated that the effect of lesioning affected in a different way the performance related to the three tasks. The authors demonstrated that perceptual similarity can impair naming and object decision performance without affecting other types of tasks, such as semantic categorisation. However, a lesion to the structural descriptions units led to an impairment for the most visually similar stimuli, namely, living things, both in the object decision task and in naming, although in the latter task the effect was of higher magnitude. This result may thus reflect those described in patients with category specific deficits for living things. However, the introduction of an even more extensive lesion to the mappings from structural to semantic pools of units and from semantic to name units led to an equal effect on structurally similar (living) and dissimilar (artefacts) items. Therefore, the emergence of the opposite dissociation, that of a category specific deficit for visually dissimilar stimuli, namely, artefacts, with respect to visually similar items (living things) was not found in this study. In conclusion, the findings discussed by Humphreys and co-workers (1995) present limits that highlight the general inadequacy of this model in accounting for category specific phenomena and should therefore be evaluated with caution. In effect, even though this model can account for different types of performance over different tasks in patients showing a category specific effect, selective deficits for living things cannot be ascribed with certainty to the selective breakdown of a singular component of the model, as outlined above. Moreover, the model failed to simulate category specific deficits for man-made artefacts.

An explanation of category specificity effects as resulting from non-categorical properties of semantic representations was put forward by Caramazza and co-workers in recent years (Caramazza, Hillis, Rapp, Romani, 1990; Hillis, Rapp, Caramazza, 1995; Rapp, Hillis Caramazza, 1993). The Organised Unitary Content Hypothesis (OUCH model) is based on two principal characteristics which are held to be representative both in the case of living things and man-made artefacts: first, the properties concurring to the definition of a concept are highly intercorrelated; secondly, the members belonging to the same superordinate category have in common many features. What differentiates living things from man-made artefacts is that the former category shares far more intercorrelated features than the latter. The bunches of intercorrelated features are held to occupy different regions within a multidimensional space of semantic properties in a non homogenous fashion. As a consequence, "the denser regions represent concept domains characterised by highly correlated properties, with the densest regions most likely corresponding to natural kind concepts" (Caramazza and Shelton, 1998). In general, the OUCH model predicts the emergence of category specific deficits without any need to hypothesise a categorical organisation of the semantic memory system. Several predictions follow from this theoretical position: a focal lesion localised in a given brain region will affect those categories whose properties are represented in that part of the semantic space, and since the distribution of semantic properties in this space is not homogeneous, focal damage is likely to affect one category more than another. Moreover, since highly correlated properties correspond to denser regions of the semantic space, those categories characterised by highly correlated properties are more likely to be selectively affected as a whole. Another implication of the model's assumptions is that category specific deficits might arise in a variety of patterns, depending on the patchy distribution of bunches of densely intercorrelated features. More importantly, highly intercorrelated features are held to involve both sensory and functional properties of a given concept, so that the selective deficit affecting a semantic category is claimed to be independent of the disproportionate impairment of visual/functional properties.

This last prediction, which critically challenges the original functional/sensory distinction account put forward by Warrington and Shallice (1984) seems to be virtually the only testable assumption of the view proposed by Caramazza and colleagues. Moreover, it seems worth noting that the other assumptions of the model are too unconstrained and can account for any kind of category specific deficit, from the most classical to the most peculiar fractionations of categorical knowledge.

In a subsequent work, Caramazza and colleagues reviewed the position proposed with the OUCH model, hypothesising that the semantic system may be organised in a categorical fashion. In Caramazza and Shelton (1998), the assumption that evolutionary adaptations are responsible for a categorical organisation of semantic knowledge is adopted. In the view of these authors, it is more appropriate to assume that evolutionary pressures led to specific adaptations for the identification of animals and plants. The survival value of these adaptations is obvious: animals are potential predators, but also potential sources of food; plants as well, are a source of food and medicine. In terms of neural and functional mechanisms, the relevant adaptations might consist, respectively, of dedicated neural circuits —or specialised cognitive processes— for processing information about animals and plants. This process would lead to the organisation of a complex system of knowledge, in which the categories of animals and vegetables are separated from the representation of other categories, such as utensils. Consequently, on Caramazza and Shelton's (1998) view, the only pure category specific deficits will consist of those involving animals and plants and, by contrast, man-made artefacts, while other finer-grained distinctions should not be observed.

There is a further implication of the hypothesis of the existence of dedicated neural circuits for the categories of living things and foods, which are assumed to share some of the neural circuitry devoted to the processing of animals and plant information. The observation of a deficit affecting animals or fruits and vegetables may be paralleled by the description of a comparable damage affecting the category of foods, even though many exemplars of this category are generally classified as man-made artefacts.

The organisation of the conceptual system of knowledge of the world is assumed to develop through the acquisition of the properties that characterise a given exemplar of a category. For living things fundamental properties might be their internal structure (e.g. organs), self-initiated and intentional motion (see Mandler, 1992; Mandler and McDonough, 1996); in the case of man-made artefacts a critical property might consist on their function. However, Caramazza and Shelton state that perceptual features are not intrinsically critical for a distinction between categories, functioning merely "as cues to category membership. However, the categorical distinction is fundamental and precedes the acquisition of specific perceptual facts about their members".

A quite different position has been proposed by Gonnerman et al. (1997) and Devlin et al. (1998). Gonnerman and colleagues described a striking pattern of impairment between living things and man-made artefacts: it was observed by Gonnerman and colleagues that AD patients in the early stage of their illness show an opposite category specific deficit, involving artefacts, but as the disease progresses the effect reverses with living things categories becoming massively affected. Knowledge of man-made artefacts categories, however, gradually becomes unavailable only for individual items in the class, without showing the massive loss that is observed with living things. Thus the living things deficit is observed for the more severely affected patients.

This reported pattern of results on AD patients was simulated by Devlin et al. (1998) in a connectionist model. The basic assumptions of the model are that concepts are represented as distributed patterns of activation of semantic features in the semantic system. This feature set is held to include both perceptual attributes and functional properties, which differentially contribute to the characterisation of a concept. On their account, two important factors are held to be responsible for the organisation of semantic features in the system of knowledge. Firstly, semantic features can be intercorrelated, when they are common to a number of items within a class.

Living things have many more intercorrelations among features than do man-made artefacts and thus are more strongly interconnected. A second characteristic of the semantic system consists of distinguishing features, which occur almost exclusively for singular items within a category, therefore allowing the differentiation of a concept from related ones. The distinguishing features for animate objects tend to be perceptual rather than functional, while the opposite pattern is found for man-made artefacts. Thus, sensory properties generally allow a distinction among living things, while functional properties tend to differentiate between man-made artefacts. The presence of strong intercorrelations among exemplars of the living thing classes is held to produce a marked non-linearity in the pattern of deterioration of semantic ability in AD, as claimed by Gonnerman et al. (1997). Initially, the redundancy of the connections between intercorrelated features protects living items from loss. On Gonnerman et al.'s (1997) and Devlin et al.'s (1998) theory, as damage increases, however, a critical mass of intercorrelated features becomes unavailable, consequently leading to the disruption of the knowledge of the entire class. With man-made artefacts, however, distinguishing features become isolated even with very little damage, because of the lack of intercorrelations between features, thus reducing the differentiation of individual man-made artefacts from other members of that category. At later stages of the illness, a loss of individual items across different categories within the artefact class is observed, as a consequence of the isolation of an increasing number of individual features. On these grounds, it is held that a different pattern occurs across the two types of category in the loss of concepts: artefact knowledge decreases linearly during time, while a cross-over is observed with living things: initially living things are better preserved than man-made artefacts, whereas, over time, their knowledge decays more rapidly than that concerning man-made artefacts.

However, a critical problem for the theory is that the empirical results on which it is based have been challenged by Garrard et al. (1998), who failed to replicate with their group of 58 AD patients, the pattern of deterioration Gonnerman et al. (1997) found. A further critique may come from a work (Tippett et al., 1996) which demonstrated that AD patients showing a category specific effect associated to an advantage for man-made artefacts, vanished when the stimulus set was balanced in terms of familiarity, prototypicality —as also performed in a study by Silveri et al. (1991)—, and also frequency, and visual complexity.

In addition, Devlin's et al. connectionist model was tested by Perry (1999), in order to verify whether the model can generalise to the addition of new exemplars, is expandable such that training sets of a realistic size can be used, is resilient to small changes in the architecture; a final purpose of this simulation is concerned with the possibility to reproduce results that can be compatible with the principal findings described in clinical studies of patients with selective impairments affecting the semantic system organisation. Devlin's model was found to be faulty in all four test carried out by Perry. It is be also worth noting that Devlin's et al. model was specifically implemented to address the emergence of category-specific deficits in patients with AD. The random damage to the distributed network might be a plausible approximation to the widespread damage occurring in AD, but it is less convincing when it has to be applied to the behaviour typically associated to other aetiologies which are characterised by more focal damages, such in the case of HSE.

A quite different view, which takes into account the observations coming from cognitive impairments as well as neurological/neuroanatomical considerations, is held by Lambon Ralph et al. (1998). The authors describe two neuropsychological cases. One, DB, was an AD patient with a category specific deficit which affected living things in naming and comprehension tasks; she did not show any difference between attribute type (perceptual vs. functional-associative) when her knowledge about living things and man-made artefacts was assessed. The other patient, IW, suffered from semantic dementia: she showed a slight advantage for this class of stimuli with respect to man-made artefacts; however, she had an impairment in retrieving perceptual attributes of concepts while her knowledge of functional-associative information was spared. From the observation of these two patients the authors propose that semantic knowledge is based on a combination of information coming from sensory association areas, encoded and analysed within the temporo-limbic areas. Concepts would be represented by the distributed pattern of <u>activation</u> across each associative cortex and by a bunch of <u>interconnections</u> between them and the temporo-limbic regions. In these authors' view an impairment for a particular type of attribute does not necessarily involve a category-specific deficit: other critical characteristics related to a concept could be activated by a direct sensory input; in addition, the pattern of interconnections between undamaged areas of the semantic system might support the activation of spared knowledge about attributes of concepts.

An alternative view is put forward by Bloom (1996), and, on similar grounds by Malt and Johnson (1998). Basing his arguments on a philosophical perspective, Bloom claims that the membership of an artefact kind is determined by the <u>inference</u> that a given object was "successfully created with the intention to belong to that kind". From these premises, the author argues that in our understanding of objects, a critical role is played by properties such as the shape of an object, much more than other characteristics, such as its function, or physical characteristics, such as its colour. For example, *chairs* tend to be characterised by a similar shape, just because they reflect the intention of their creator of making a chair. In contrast, many objects can have the function of, say, a chair, even though they were not created with this specific purpose. However, it has to be stressed that only our intuition of the intention underlying the building of a chair allow us to deal with other properties of chairs: the "typical" function of a chair is clear when we look at an objects with a "typical" shape, that corresponding to chairs. Therefore, in our understanding of objects, "intention", which is fundamental in determining category membership, shares a direct link with "shape", and then "shape" suggests a consequent link to "function". At variance, chairs may have different colours or can be made of different materials, but a change in these properties does not modify our knowledge of what a chair is. Therefore these latter physical properties are not core features of man-made artefacts concepts. Bloom's theoretical position might also give an explanation for the reason why certain objects kinds are categorised as members of the man-made artefacts class even though they are highly dissimilar from other exemplars of the same semantic domain, on the light that they all share the same initial "intention" of being created to belong to that same kind.

A similar position was proposed by De Renzi and Lucchelli (1994). Their view is that the distinction between living things and man-made artefacts consists not in the proportion of different kinds of features, functional vs. perceptual, which characterise a concept, but in their relationship to each other. They stressed that a fundamental relation between form and function is observed mostly for man-made artefacts: therefore the function of an object frequently places strong constraints on its form. These authors argue that, in the case of animals and plants, similar form-function relations do not exist, thus leading to a disproportionate difficulty in dealing with the processing of living things —and also other types of stimuli— where the form-function relation is not as strong as for man-made artefacts.

The position held by Tyler and Moss (1997) is somewhat related but different. They claim that such form-function relations also exist for living things, referring to biological functions like breathing, reproducing and eating (Moss, Tyler and Jennings, 1997). The authors' view takes support from the findings of developmental researches, which state that children learn to distinguish between living entities and artefacts in terms of the modality in which they interact with the environment (Mandler, 1992; Mandler and McDonough, 1996). From their developmental perspective, Mandler and co-workers describe that children interpret the category membership of an object through a general analysis of the <u>movements</u> and <u>spatial relations</u> that characterise the event which the object takes part to: therefore, functional information (referred to as the way of interaction with the environment) is held to pertain to both living things and artefacts as a result of the <u>same</u> cognitive process.

On the Tyler et al.'s (in press) view, the inter-dependency between perceptual and functional properties is the core concept of their theoretical position. In the case of artefacts, a strong link characterises the form of an object (its perceptual characteristics) to its function. Artefacts functions tend to be highly specific, in that they usually have a unique function, associated to a "distinctive" perceptual property. The "shared" perceptual features of man-made artefacts, however, are not associated with a specific function, being rather linked to the general context in which an object is used. On the other hand, living things are thought to be strongly characterised by shared perceptual properties which are closely related to shared biological functions, which are held to be common to many exemplars of the category. In contrast, distinctive perceptual attributes of living entities are not usually associated with biological functions. In the Tyler et al.'s (in press) model, "distinctive functional information co-occurs with distinctive perceptual features" in the artefacts case, whereas "for living things biological functional information ... co-occurs with shared perceptual features". On the basis that highly correlated features are more resistant to damage than weakly correlated properties, "distinctive perceptual attributes for artefacts and shared features for biological kinds will be correlated with functional information and will be the most resistant do damage". From their model several predictions follow, although, as the authors claim, two factors will influence the model behaviour, namely severity of damage and task demands: (i) an impairment to the living things class will emerge more frequently because their distinctive properties are less correlated and therefore more prone to damage. However, this deficit will be detectable on those tasks which require a fine-grained distinction among exemplars within a category in order to be performed (naming and inter-category matching tasks); (ii) a widespread loss of perceptual knowledge associated to living things is not predicted, at variance with Warrington and Shallice's (1984) theoretical view, since shared features are expected to be well preserved; (iii) given that, in the case of artefacts, the highest (but still not remarkable) amount of correlation characterises distinctive features, no conspicuous differences should be observed as regards the relative advantage of shared vs. distinctive features; (iv) a selective deficit affecting artefact knowledge relative to living things should occur only in the case of severe damage to the semantic system, contrary to the Gonnerman et al.'s (1997) and Devlin et al.'s (1998) position; this is explained on the basis that only living things have highly shared correlated features, which can sustain patient's performance, while artefacts are characterised by shared and distinctive features that are not highly correlated.

Therefore, these form-function relations can be conceived as correlations between features in a distributed network (Tyler and Moss, 1997): the activation of the function features will therefore enhance the probability of an activation of the form features, although the contrary is not always true. The importance of functional properties of living things, such as the biological-functional properties, different from the associative-encyclopaedic attributes, is strongly stressed by Tyler and Moss (1997); nevertheless it is worth noting that these biological-functional properties belong to all members of categories of living things (e.g. all animals), and, in this sense, they seem more likely to be considered as "superordinate" attributes, which, as reported in a large number of studies, are often preserved after cerebral damage. Moreover, since the authors themselves claim that their "model is similar in many respects to that of Devlin et al. (1998)", a test of the model should perhaps be performed also in this case, as Perry (1999) had done in the case of Devlin's model.

3.4 Neural correlates of category specific deficits in different pathologies

The observation of category specific deficits has led to a long lasting debate as regards the cerebral areas involved in the processing of different categories of knowledge. Both studies on patients with brain damage and on normal subjects suggest that the cortical representations of different kinds of concepts may be associated to separated regions of the brain. The obvious tendency to link theoretical accounts of category specificity to cognitive processes engaged by different cerebral areas gave rise to an increasing number of studies aimed at determining the brain regions involved in such processes.

Therefore, the examination of both the lesion patterns shown by patients with category specific deficits (section 3.4.1) and of functional imaging studies (section 3.4.2), performed on normal subjects when dealing with either living things or man-made artefacts stimuli, will be performed in the following sections. Finally (section 3.4.3), the attempt will be made to match lesion data and functional imaging findings, in order to determine which brain regions have been found to be the most frequently involved as respect to either living things or man-made artefacts processing.

3.4.1 Lesion studies

So far, a relative difficulty in naming living things has been commonly associated to posterior and ventral lesions (Saffran and Schwartz, 1994), whereas selective deficits affecting the knowledge of man-made artefacts have been usually related to damages localised in anterior and dorsal areas (Saffran and Schwartz, 1994; Gainotti et al., 1995).

In the following section (3.4.1.1) a more detailed description of the pattern of lesions found in patients affected by HSE either showing or not showing a category specific deficit will be presented. In a further section (3.4.1.2), the pattern of cerebral damage observed in patients who have suffered from aetiologies different from HSE, but showing a category specific deficit, will be thoroughly described.

From the examination of the lesion data emerging from different pathologies, but always leading to a category specific deficit, an attempt will be performed to indicate the regions which seems the most frequently involved in this phenomenon.

3.4.1.1 Lesion data in HSE patients

HSE patients typically show bilateral damage to temporo-limbic regions, such as anterior and medial temporal cortices, associated to lesions to the inferior temporal lobes. A brief survey of the damaged regions in HSE patients who did not show a category specific impairment will be firstly presented.

Patient SS, described by Verfaellie et al. (1995), was a densely amnesic patient, whose learning abilities were found to be impaired. His cerebral damage involved bilaterally the medial temporal lobes, insula and temporal poles; only the lateral aspects of the temporal poles were spared, except the anterior tip of the middle and superior left temporal gyrus.

Reed and Squire (1998) described the case of two patients who became densely amnesic after an episode of HSE. Their retrograde amnesia involved the memory of both facts and events. In both patients a bilateral lesion of the temporal lobes including the hippocampal formation was observed, although one of the patients, EP, showed particularly damaged areas in the medial temporal regions and in the laterally adjacent fusiform gyrus.

Patient LD, reported by Eslinger et al. (1993), who suffered from HSE, showed an impaired non-verbal learning and a non-verbal retrograde amnesia. However, her verbal learning and retention were only mildly affected. The extensive examination of the patient's lesion pattern performed by the authors showed that the right hemisphere was the most compromised. In fact, she had a damage involving massively the right temporal lobe structures: the temporal pole, the medial temporal regions, including hippocampus and parahippocampal gyrus, the anterior half of the superior temporal gyrus, all the middle and inferior parts of the temporal gyri and the insula. The patient cerebral damage extended also to the majority of the structures of the right hemisphere: the most anterior and inferior portions of the cingulate were damaged, as well as the posterior ventro-medial parts of the frontal lobe, including the basal forebrain and the gyrus rectus. The lesion extended also to the inferior parietal lobule, compromising part of the supramarginal gyrus, most aspects of the angular gyrus and the lateral occipital lobe. In the left hemisphere, patient LD showed lesions limited to the collateral sulcus, the inferior portion of the insula and minimal damages to the posterior ventro-medial areas of the frontal lobe.

Three patients with HSE, who did not show a category specific effect in visual confrontation naming, were described by Barbarotto et al. (1996). Two patients, GG and MG, were found to have damage restricted to the left hemisphere, involving the temporal basal and lateral regions, the insula, the hippocampus and the parahippocampal gyrus. Patient GG also presented a thalamic damage. The third patient, AM, showed a right temporo-parietal damage, bilateral fronto-temporal attenuation, predominantly in the right side, and a lesion to the right hippocampus.

The examination of the lesion sites most commonly damaged after an episode of HSE in patients who did show a category specific deficit for living things will de described in the remaining of the present section (see table 2 for an outline of the lesion sites damaged in these patients). Patients' lesion data will be reported below on the basis of the lesion extension in the temporal lobe and, where found, beyond the temporal lobe. Therefore, first were considered patients showing only a unilateral or bilateral temporal involvement. In a second step, the lesion pattern of patients with a unilateral or bilateral temporal damage, but associated to damage to other cortical structures was examined. Finally, the involvement of limbic, frontal and occipital regions was described.

1) Patients showing only temporal damage.

Two patients showed cortical damage involving only the left temporal lobe. Ferreira and colleagues (1997) described a patient, VG, who was worse at naming animals with respect to actions and tools, and presented lesions affecting the left medial infero-temporal regions.

Patient SB (Sheridan and Humphreys, 1993), showed a selective deficit for living things and foods with respect to man-made artefacts, which were however found to be also mildly impaired. The patient was shown to have damage affecting the left temporal regions.

A series of other HSE patients presented bilateral lesions involving the temporal lobes only. Michelangelo, described by Sartori and Job (1988), presented a category-specific deficit affecting in particular animals, fruits and vegetables. A CT scan showed the bilateral involvement of the anterior parts of the temporal lobes.

A second patient described by Ferreira et al. (1997), PR, demonstrated naming difficulties with animals relative to tools and actions: in this case the lesion extended to the left medial inferior and the right inferior temporal areas.

An impairment involving living things was also observed in patient RM, while another patient, JV showed a deficit restricted to plants (Pietrini et al., 1988). Both patients had bilateral lesions to the inferior and middle temporal gyri, which were predominant on the left. Further damage was observed for both patients in the left insula.

In their original account of category specificity, Warrington and Shallice (1984) described four HSE patients. All patients (JBR, SBY, KB and ING) showed an impairment of their semantic knowledge for living things and foods relative to the preservation of their ability to deal with man-made artefacts. The whole group of patients presented cerebral damage affecting bilaterally the temporal lobes, which was most marked on the left side in patient KG.

2) Patients showing temporal damage associated to lesions involving also other structures.

Two patients have been reported to have a temporal involvement limited to the left side, along with other lesions beyond the temporal lobe (these associated damages will be described in detail below). A large group of patients who had suffered from HSE was described by Barbarotto et al. (1996). However, in some of the patients belonging to the experimental group (FA and FI) a category specific deficit affecting selectively the living things class was reported. Unfortunately, all the patients were assessed only through the administration of a visual confrontation naming task. Therefore, no clear conclusions can be drawn about the possibility of a category specific involvement of their semantic knowledge. Patient FA was damaged in the left temporo-lateral regions, while FI presented lesions compromising the left temporal basal and lateral regions and the insula.

In the literature, a single HSE patient was reported to have a major compromising localised in the right temporal lobe. Patient SE was firstly described by Laws et al. (1995), and only when later studied by Moss et al. (1997) was found to have a category specific deficit for living things. SE's lesion site was located on the right temporal pole and the infero-lateral temporal gyri at the level of the insula. However, the left temporal lobe seemed to be unaffected.

In a number of cases, however, the bilateral compromising of temporal lobes (along with the impairment of other structures, see below) was described. Patient MS, described by Young et al. (1989) and in a subsequent work by Metha et al. (1992), was impaired as respects to the living things class in comparison to artefacts. The patient showed severe damage, affecting bilaterally the temporal regions and the left fourth temporal gyrus. More precisely, MS's damage to the temporal lobes involved the temporal pole, the fourth, third and second temporal gyri and the anterior part of the first temporal gyrus.

In the study by Barbarotto et al. (1996) described above, two patients, LF and EA, showing a naming impairment for living things, presented with bilateral lesions of the temporal lobes: both patients had lesions in the left temporal basal and lateral areas and the insula, while in the right hemisphere they showed damage to the temporo-basal areas. A further neurological examination, of patients LF and EA, already described in Barbarotto et al. (1996) was performed in a subsequent study by Laiacona et al. (1997). The authors assessed patients' knowledge with a larger set of tasks, and a category specific deficit affecting the patients' semantics of living things could be ascertained. A further examination of the patients' lesions was performed by the authors. Patient LF showed damage involving the whole left temporal lobe, and only the posterior regions of the middle and superior temporal gyri were spared; furthermore he had an atrophy in the right temporal basal areas. The second patient, EA, showed severe lesions of the anterior half of the left temporal lobe and of the middle and inferior temporal gyri. Some alteration were also found in the Wernicke's area and in the deep white matter of the posterior temporal lobe. On the right side, less severe damage was localised in the anterior part of the lateral occipito-temporal gyrus.

Patient RC, reported by Tyler and Moss (1997) and Moss et al. (1998a, b) developed a category specific deficit for living things after HSE. The MRI scan showed an extensive lesion, which affected bilaterally the temporal lobes and was more marked on the left side. Damage extended from the lateral surface anteriorly, through the medial and inferior surface more posteriorly.

A category specific deficit affecting the knowledge of living things was reported (De Renzi and Lucchelli, 1994) in a patient, Felicia, who had a diagnosis of viral encephalitis. In her case, a CT scan showed areas of hypodensity localised bilaterally in the temporo-insular regions. An MRI scan showed a bilateral lesion of the antero-medial regions of the temporal lobes, which was most marked on the left. In the left hemisphere, damaged regions were observed in the temporal pole, the temporal white matter and the cortex of the anterior half of areas 21 and 22; in addition, the insula presented signs of atrophy. On the right hemisphere, lesions were found in the temporal pole and in the medial temporal areas.

Wilson et al. (1995) reported the case of a patient who showed a specific deficit affecting the knowledge of living things. Patient C had a lesion involving bilaterally the temporal poles, the left inferior temporal gyrus, the anterior portion of the left middle and superior temporal gyrus, and the left insula.

A selective impairment for living things was also reported by Sartori et al. (1993b) in a patient who recovered from an episode of HSE. Patient Giulietta had a damage involving bilaterally the temporal lobes.

Patient CW (Wilson, 1997), presented a deficit affecting the semantic knowledge of living things with respect to man-made artefacts. The patient showed damage affecting both temporal lobes.

Finally, Silveri and Gainotti (1988), described a patient, LA (reassessed also by Gainotti and Silveri, 1996), who recovered from herpes simplex encephalitis. The patient's knowledge of living things and foods was selectively impaired, in particular when the visual modality was involved. The patient showed a bilateral temporal involvement, most marked on the left side. Unfortunately, in these last three cases no further details on the temporal areas specifically involved were given by the authors.

3) Associated lesions in non-temporal areas.

Along with the temporal lobe damage, constantly reported in HSE patients, an involvement of the limbic structures is often described to occur. Patient FI (Barbarotto et al., 1996) had a selective impairment in naming living things. The patient presented lesions affecting the hippocampus and the parahippocampal formation on the left side.

A second patient reported in this study, EA, showed also a left sided damage to the hippocampus and the parahippocampal formation. In a later study by Laiacona et al. (1997), patient EA presented a lesion, though not very severe, to the left parahippocampal gyrus and in the white matter of the left hippocampus.

Patient Felicia, described by De Renzi and Lucchelli (1994) showed in the left hemisphere damaged areas affecting the uncus, the hippocampus and the parahippocampal gyrus.

Bilateral damage to the limbic structures were also described in a series of studies. Tyler and Moss (1997) and Moss et al. (1998a, b) reported the case of patient RC, who had a bilateral lesion also involving the caudate nuclei and the hippocampal formation.

Patient SE (Laws et al., 1995; Moss et al., 1997) was found to have damage including left uncus and amygdala and, on the right side, hippocampus, the parahippocampal gyrus.

Patient C (Wilson et al., 1995) was found to have a lesion extending bilaterally to the limbic regions.

The bilateral involvement of the hippocampal regions was also described in patient Giulietta (Sartori et al., 1993b).

Patient MS (Young et al., 1989; Metha et al., 1992) presented with bilateral lesion areas in the parahippocampal formation, particularly in the anterior portion.

Barbarotto and colleagues (1996) reported the presence of limbic damage in patient LF (see also Laiacona et al., 1997): the hippocampus and the parahippocampal formation on the left side, and the parahippocampal gyrus on the right were compromised.

The limbic structures were involved bilaterally also in patient CW (Wilson, 1997).

Likewise, patient LA (Silveri and Gainotti, 1988; Gainotti and Silveri, 1996) was found to have lesion areas localised bilaterally in the limbic system.

In HSE patients frontal damage is also quite frequently reported and a left sided involvement has been described in three cases. Areas of hypodensity localised in the fronto-basal areas of the left hemisphere were found in patient Felicia, along with damage to the gyrus rectus, bilaterally (De Renzi and Lucchelli, 1994).

In patient LF (Barbarotto et al., 1996; Laiacona et al., 1997) a left fronto-mesial lesion, with signs of atrophy in the infero-medial parts, was also observed.

Wilson (1997) reported the presence of lesions in the inferior and posterior regions of the left frontal lobe in patient CW.

The bilateral involvement of frontal areas has been reported in two further cases. Patient FA (Barbarotto et al., 1996) had damaged regions in the left basal and mesial parts of the frontal lobe and a fronto-mesial involvement was also found in the right hemisphere.

A bilateral frontal lesion was also described in patient LA by Silveri and Gainotti (1988) and Gainotti and Silveri (1996).

In some instances the occipital lobes are found to be affected in HSE patients. A severe damage, affecting bilaterally the temporo-occipital regions was reported in patient MS (Young et al., 1989; Metha et al., 1992): more precisely, the mesial and lateral parts of the occipito-temporal junction were destroyed, as were the mesial and lateral aspects of the occipital lobes.

Likewise, patient EA (Laiacona et al., 1997) showed damaged areas in the left medial and lateral occipito-temporal gyri, while in the right hemisphere, a small alteration was observed in the anterior part of the lateral occipito-temporal gyrus.

Table 2: Lesion sites in HSE patients who developed a category-specific deficit

Lesion site		
L temporal	JBR, SBY, KG, ING; SB; CW; C; RC; RM, JV; Felicia; Giulietta; MS; LA; VG, PR; SE; FI, LF, EA, FA; Michelangelo	Warrington & Shallice, 1984; Sheridan & Humphreys, 1993; Wilson, 1997; Wilson et al., 1995; Tyler & Moss, 1997/ Moss et al., 1998a, b; Pietrini et al., 1988; De Renzi & Lucchelli, 1994; Sartori et al., 1993b; Young et al., 1989/ Metha et al., 1992; Silveri & Gainotti, 1988/Gainotti & Silveri, 1996; Ferreira et al., 1997; Laws et al., 1995/Moss et al., 1997; Barbarotto et al., 1996//Laiacona et al., 1997; Sartori & Job, 1988
R temporal	JBR, SBY, KG, ING; CW; C; RC; RM, JV; Felicia; SE; Giulietta; MS; LA; EA; PR; Michelangelo	Warrington & Shallice, 1984; Wilson, 1997; Wilson et al., 1995; Tyler & Moss, 1997/ Moss et al., 1998a, b; Pietrini et al., 1988; De Renzi & Lucchelli, 1994; Laws et al., 1995/Moss et al., 1997; Sartori et al., 1993b; Young et al., 1989/ Metha et al., 1992; Silveri & Gainotti, 1988/Gainotti & Silveri, 1996; Barbarotto et al., 1996/Laiacona et al., 1997; Ferreira et al., 1997; Sartori & Job, 1988
L Temporal bas	FI, LF, EA, FA	Barbarotto et al., 1996/Laiacona et al., 1997
R Temporal bas	EA, LF	Barbarotto et al., 1996/Laiacona et al., 1997
L Temporal lat	FI, LF, EA, FA; RC	Barbarotto et al., 1996/Laiacona et al., 1997; Tyler & Moss, 1997/ Moss et al., 1998a, b
R Temporal lat	RC; SE	Tyler & Moss, 1997/ Moss et al., 1998a, b; Laws et al., 1995/Moss et al., 1997
L Temporal med	RC; RM, JV; C; Felicia; VG, PR	Tyler & Moss, 1997/ Moss et al., 1998a, b; Pietrini et al., 1988; Wilson, 1997; De Renzi & Lucchelli, 1994; Ferreira et al., 1997
R Temporal med	RC; RM, JV; Felicia	Tyler & Moss, 1997/ Moss et al., 1998a, b; Pietrini et al., 1988; De Renzi & Lucchelli, 1994
L Temporal inf	RC; RM, JV; C; VG, PR	Tyler & Moss, 1997/ Moss et al., 1998a, b; Pietrini et al., 1988; Wilson, 1995; Ferreira et al., 1997
R Temporal inf	RC; RM, JV; PR; SE	Tyler & Moss, 1997/ Moss et al., 1998a, b; Pietrini et al., 1988; Ferreira et al., 1997; Laws et al., 1995/Moss et al., 1997
L Temporal ant	Michelangelo; C; Felicia	Sartori & Job, 1988; Wilson, 1997; De Renzi & Lucchelli, 1994
R Temporal ant	Michelangelo; Felicia	Sartori & Job, 1988; De Renzi & Lucchelli, 1994
L Temporal pole	MS; C; Felicia	Young et al., 1989/ Metha et al., 1992; Wilson et al., 1995; De Renzi & Lucchelli, 1994
R Temporal pole	MS; C; Felicia; SE	Young et al., 1989/ Metha et al., 1992; Wilson et al., 1995; De Renzi & Lucchelli, 1994; Laws et al., 1995/Moss et al., 1997
L insula	FI, LF, EA; RM, JV; C; Felicia	Barbarotto et al., 1996/Laiacona et al., 1997; Pietrini et al., 1988; Wilson et al., 1995; De Renzi & Lucchelli, 1994
R insula	Felicia	De Renzi & Lucchelli, 1994
L limbic structures	FI, LF, EA; Giulietta; LA; RC; MS; CW; C; Felicia; SE	Barbarotto et al., 1996/Laiacona et al., 1997; Sartori et al., 1993b; Silveri & Gainotti, 1988/ Gainotti & Silveri, 1996; Tyler & Moss, 1997/ Moss et al., 1998a, b; Young et al., 1989/ Metha et al., 1992; Wilson, 1997; Wilson et al., 1995; De Renzi & Lucchelli, 1994; Laws et al., 1995/Moss et al., 1997
R limbic structures	Giulietta; LA; RC; MS; CW; C; SE; LF	Sartori et al., 1993b; Silveri & Gainotti, 1988/ Gainotti & Silveri, 1996; Tyler & Moss, 1997/ Moss et al., 1998a, b; Young et al., 1989/ Metha et al., 1992; Wilson, 1997; Wilson et al., 1995; Laws et al., 1995/Moss et al., 1997; Barbarotto et al., 1996/Laiacona et al., 1997
OTJ med-lat	MS	Young et al., 1989/ Metha et al., 1992
L Occipital	MS	Young et al., 1989/ Metha et al., 1992
R Occipital	MS	Young et al., 1989/ Metha et al., 1992
O med-lat (bil)	MS	Young et al., 1989/ Metha et al., 1992
L O med-lat	EA	Barbarotto et al., 1996/Laiacona et al., 1997
R O ant-lat	EA	Barbarotto et al., 1996/Laiacona et al., 1997
L Frontal	LA; CW; Felicia; LF	Silveri & Gainotti, 1988/Gainotti & Silveri, 1996; Wilson, 1997; De Renzi & Lucchelli, 1994; Barbarotto et al., 1996/Laiacona et al., 1997
R Frontal	LA, FA	Silveri & Gainotti, 1988/Gainotti & Silveri, 1996
L Frontal inf	CW	Wilson, 1997
L Frontal post	CW	Wilson, 1997
L Frontal bas	Felicia	De Renzi & Lucchelli, 1994
L Frontal med	LF, FA	Barbarotto et al., 1996/Laiacona et al., 1997
R Frontal med	FA	Barbarotto et al., 1996

To summarise (see table 2), HSE patients with category specific deficits for living things with respect to man-made artefacts always present extensive lesions affecting one or both the temporal lobes: the damage usually affects lateral, medial, inferior and basal temporal regions, and is in some instances more marked in the anterior parts, while only in few cases also a posterior involvement is shown. Limbic structures such as hippocampus and parahippocampal formation more frequently, and caudate, uncus and amigdala far less frequently, are also involved unilaterally or bilaterally. Frontal damage is also frequently reported, and the inferior, medial and basal regions are the most affected. The lesion pattern tends to involve in some instances also the temporo-occipital areas, again showing a major involvement of the lateral and medial regions.

HSE patients who do not show a category specific impairment for living things relative to man-made artefacts, however, tend to show a pattern of damage which generally reflects that observed in herpes patients with category specificity effects. However, at variance with the largest majority of patients who present a category specific deficit, an extensive involvement of the right hemisphere is observed in some of these cases. Additional lesions are reported to affect also the thalamus, the right temporo-parietal regions and the inferior parietal lobule.

3.4.1.2 Lesion data in other aetiologies

As pointed out in section 3.2.3 of this chapter, category specific deficits, either for living things or man-made artefacts, have been described also in patients who suffered from pathological diseases other than HSE. In this section, the lesion sites found to be damaged in patients who, although not being herpes patients, developed a category specific deficit will be reviewed. Firstly, the cerebral damages found in patients showing a selective deficit regarding living entities will de described. Subsequently, the pattern of brain damage shown by patients who present a selective deficit for man-made artefacts with respect to living things will be reported.

Non-HSE patients with category specific deficits for living things

Tranel et al. (1997a) described a group of 116 patients with focal lesions and required them to visually recognise stimuli belonging to the categories of animals and tools. Patients who showed an impaired recognition of animals presented in general lesions localised bilaterally in mesial occipital and in the ventro-temporal cortices.

A group of 127 damaged patients was described by Damasio et al. (1996). Of the 30 patients who had an abnormal performance with animals, tools and famous faces in naming or recognition tasks, being >2sd with respect to a group of normal subjects, 29 showed a left hemisphere damage. 16 patients had an impairment with animals, but only in 5 of the cases the deficit was restricted to this category. In the remaining cases, the patients' deficit was associated to an impairment of the other two categories of stimuli. However, it has to be stressed that overall patients' abnormal performance with animals was close to that shown with tools. Afterwards, each patient's damage was reconstructed and analysed in order to define their lesion pattern: abnormal naming of animals correlated to damage of the left anterior infero-temporal cortex.

Hillis and Caramazza (1991) described the case of a patient, PS, who suffered from a sustained brain injury from a severe blow to his head. The patient was poorer on animals and vegetables with respect to other semantic categories over seven sessions of a visual confrontation naming task. Patient PS had damages in both temporal lobes, more prominent in the left side, and small lesions in the frontal lobes.

In a single case study of Cardebat et al. (1996), a patient with a mild dementia of Alzheimer's type and left inferior cortical atrophy was described. The patient showed a category specific deficit severely affecting her semantic knowledge of animals in contrast to a good performance with objects. The patient's lesion involved the left inferior temporal cortex.

A semantic dementia patient, MF, described by Barbarotto et al. (1995), showed a semantic deficit for living things; in contrast, his knowledge of man-made artefacts was found to be spared. The examination of the patient's brain damage revealed lesions localised in the lateral and basal aspects of both temporal lobes, more severe in the right hemisphere, with a further involvement of the basal neocortex, the hippocampal and parahippocampal gyri.

Non-HSE patients with category specific deficits for man-made artefacts

In the same group study discussed previously in this section, Tranel et al. (1997a) found that patients with an impaired recognition of tools generally have a lesion to the left lateral occipital-temporal-parietal junction.

Damasio et al. (1996) presented findings from a group study already described above, highlighting that patients with a deficit for tools tend to show damage localised in the left postero-lateral inferior temporal lobe and in the lateral temporo-occipital cortex.

In an influential single case study, Warrington and McCarthy (1983) described patient VER, who suffered from a major left hemisphere infarction. The patient had an advantage for living things and foods relative to objects. Her lesion was localised in the left fronto-parietal regions.

In a further study (Warrington and McCarthy, 1987), the comprehension skills of a patient, YOT, who became global dysphasic after a stroke, were found to be generally affected in the case of man-made artefacts, in particular with small manipulable objects, while the patient showed much a better performance with living things and foods. The patient presented a lesion in the left temporo-parietal areas, and the left lateral ventricle was larger than the right one.

Patient JJ (Hillis and Caramazza, 1991) developed a category specific deficit for "non-animals" categories relative to animals. The patient suffered from a thrombo-embolic stroke which compromised the left temporal lobe and the left basal ganglia.

Patient CW (Sacchett and Humphreys, 1992) suffered from a left fronto-parietal infarct and developed a category specific deficit sparing living things in contrast to artefacts and body parts. His lesion affected extensively the fronto-parietal regions.

A pronounced deficit in naming non-living things with respect to living things was reported (Silveri et al., 1997) in a patient with a progressive left hemisphere atrophy. The patient showed left temporal polar atrophy, and hypometabolism in the left middle temporal gyrus, hippocampus, parahippocampal gyrus and parietal lobule.

In conclusion, the lesion pattern shown by patients who suffered from diseases different from HSE, but who developed a category specific deficit for living things, tends to match, to some extent, the data already described for HSE patients. Left and bilateral lesions to the temporal lobes were frequently described, with involvement of inferior, lateral and basal aspects. A mild damage to frontal lobes was also observed in a case study, and additional lesions were reported to affect bilaterally the medial regions of the occipital lobes. Furthermore, an involvement of limbic structures was also reported.

In the case of a selective deficit for man-made artefacts, a much more varied pattern of lesions was observed. From a general point of view, the most general finding relates to the selective involvement of the left hemisphere, which was found in all of the cases described. However, some variability characterises the specific regions affected in patients: a fronto-parietal damage was reported, as well as temporal or temporo-parietal lesions. Furthermore, other lesion sites were reported to affect the temporo-occipito-parietal junction, the temporo-occipital regions, the inferior parietal lobule, and finally the basal ganglia.

Therefore, although some indications may come from the lesion data of both patients with HSE or other types of pathologies who developed a category specific deficit for both living things, where some consistency was observed as regard to the lesion pattern, and man-made artefacts (where only few hints are provided), further studies are needed in order to clarify the specific role of cerebral areas selectively involved in the processing of these two semantic categories.

A considerable amount of data is however provided by functional imaging studies (section 3.4.2), that examine the relative involvement of different brain regions during the processing of stimuli belonging to living things and man-made artefacts in normal subjects. The comparison of lesion data to functional imaging findings may provide further and much more reliable insight about the brain regions underlying the processing of the two semantic categories, as will be finally attempted in section 3.4.3.

3.4.2 Functional imaging studies

In recent times an increasing interest for category specificity effects has been shown in functional imaging studies. As will be described below in this section, there have been a series of areas that have been reported consistently across the majority of studies. However, a potential source of confusion might be found in the different types of experimental paradigms and sets of stimuli used in these investigations. However, despite the variability which characterise some of the findings, some clear indications have been highlighted as regards to the regions most frequently involved in the processing of the semantic categories of living things and man-made artefacts. In this section the major findings reported in functional imaging researches as respect to the living things vs. man-made artefacts dissociation will be described. Furthermore, some results regarding semantic attribute processing which may underlie category specific effects will be described. The functional imaging findings will be also confronted to the lesion data (sections 3.4.1.1 and 3.4.1.2) reported in patients showing category specific deficits.

Areas activated during living things vs. man-made artefacts processing

Activation of the extrastriate areas for living things

In a PET study (Martin et al., 1996), normal subjects were required to name pictures of animals and tools. The authors found that naming animals produced a large area of activation in the left medial occipital lobe, centred on the calcarine sulcus. However, the selective activation of the extrastriate areas in the case of both animals and tools was also reported by Perani and co-workers (1995), who investigated the difference between these categories with a matching task in which subjects were asked to judge whether two pictures were different representation of the same stimulus or, alternatively, two different items. Moreover, an increased activity of the right extrastriate medial cortex was reported by Moore and Price (1999), both in picture naming and word-to-picture matching tasks, when visually complex stimuli were presented, regardless the semantic category. In Martin and colleagues' opinion, the selective activation of the left medial parts of the occipital lobe observed while naming animals should reflect the involvement of early stages of the visual processing, which may be needed for a precise identification of stimuli, such as animals, that vary by relatively subtle differences in physical features. A similar position is also held by Moore and Price (1999), who, taking into account their results and those described by Martin et al. (1996) and Perani et al. (1995), hypothesise that a bilateral response in this area might generally relate to the high complexity of visual configuration of the stimuli. This findings are consistent with the lesion data reported by Metha et al. (1992) and Barbarotto et al. (1996, patient EA) in HSE patients with category specific deficit for living things. Moreover, a category specific deficit for living things associated to lesions to the occipital areas was also described in patients who suffered from vascular damage (Forde et al., 1997; Farah and Wallace, 1992), and in a patient with brain injury (Farah et al., 1989).

Activation of the temporal areas for living things

Damasio et al. (1996) found activation in the left infero-temporal areas in the case of animals. Increased activity for animals was however observed by Moore and Price (1999) in the right posterior middle temporal areas and in the right fusiform gyrus, in contrast to Damasio et al. (1996), who described a left inferior temporal activation, and also in contrast to Perani et al.'s (1995) findings, who found a left sided area of activity in the fusiform and lingual gyri for animals. A significant activation of the right fusiform gyrus in relation to living things, as in Moore and Price (1999), was also observed in a PET study by Cappa et al. (1998b), where subjects were required to make visual or functional/associative judgements in response to words indicating either animals or tools.

In a fMRI study (Thompson-Schill et al., 1999) subjects were involved in a semantic attribute (visual vs. non-visual) judgement task about living things and man-made artefacts. The authors found increased activity in the left middle temporal gyrus for all conditions. However, in the case of living things, both in the visual and non-visual conditions, the area of activity extended ventrally into the left fusiform gyrus, as observed for animals by Perani et al. (1995), but in contrast with Moore and Price (1999) and Cappa et al. (1998b), where right sided activity in this area was observed in the case of living things. Furthermore, in Thompson-Schill et al.'s study, the fusiform gyrus was active also when subjects were required to retrieve visual knowledge related to man-made artefacts. Therefore in the authors' view, the fusiform gyrus might play a role in the retrieval of visual information which are held to be the most critical whenever the processing of semantic representation of living things is required. This position is therefore consistent with both neuropsychological studies (Farah et al., 1989; Metha et al., 1992; Silveri and Gainotti, 1988; Warrington and Shallice, 1984) and the computational model proposed by Farah and McClelland (1991).

However, since the right posterior temporal area was also active in the case of visually complex stimuli belonging to the man-made artefacts category, Moore and Price suggest that this area might play a role in the pre-semantic structural differentiation processing of stimuli, but their position is not consistent with Tranel et al.'s (1997a) view, who associated bilateral lesions to the mesial-occipital/ventral-temporal cortex with deficits in the retrieval of conceptual knowledge related to animals. No support to Moore and Price's findings is provided by lesion data from patients with category specific deficit for living things. A selective damage to the right posterior temporal areas have never been reported in the studies described in sections 3.4.1.1 and 3.4.1.2. However, in keeping with the results of Damasio and co-workers, the left inferior temporal regions were found to be damaged in HSE patients with a category specific deficit for living entities (Barbarotto et al., 1996, patient EA), and in patients with other kinds of pathologies (Cardebat et al., 1996; Laiacona et al., 1993a, patient RG).

A selective activation for natural kinds was reported by Mummery et al. (1996) in bilateral anterior temporal areas, in a study in which subjects were asked to provide category exemplars in response to a word ("animals" vs. "tools"). Simple line drawings of living things have been found to be associated to the activation of bilateral temporal areas also in a study by Moore and Price (1999); more specifically, the activity was higher in the case of visually simple living things, like fruits, which selectively activated the left anterior temporal regions and the insula. However, this effect was not found when living things were coloured, probably because colour, in the authors' view, reduces the number of competing responses within a category (Price and Humphreys, 1989).

Therefore, the results of both Moore and Price (1999) and Mummery et al. (1996) seem to provide support to Silveri et al. (1991), who hypothesised the involvement of anterior temporal lobes bilaterally in order to find a category specific deficit for living things in mildly affected AD patients. However, it has to be stressed that, in other studies of patients in the early or moderate stages of the Alzheimer's disease, this categorical effect in favour of man-made artefacts was not reported (Tippett et al., 1996; Garrard et al., 1998). In general, the importance of the anterior temporal regions is highlighted by several studies of patients with category specific deficits for living things. This area was found to be damaged in patients with HSE by several authors (Barbarotto et al., 1996, patients EA, LF; De Renzi and Lucchelli, 1994; Moss et al., 1998 a, b). Breedin et al. (1994), in a study of a semantic dementia patient, claim that this region is involved in the processing of perceptual features, which are more relevant in the processing of living things rather than for artefacts. However, an involvement of the left anterior temporal areas have been also reported by Cappa et al. (1998a), who described a patient with a category specific deficit for man-made artefacts, limited to the lexical output level.

In Moore and Price's view, taking together the activation of the anterior (Moore and Price, 1999) and inferior (Damasio et al., 1996) temporal cortices, the "greater activity for natural objects suggests that these items increase the demands placed on object identification", as proposed also by Damasio (1990), Humphreys et al. (1988; 1995), Gaffan and Heywood (1993) and Tranel et al. (1997b).

Other areas of activation for living things

Additional small areas of activation related to animals were observed in the frontal regions (Martin et al., 1996). Likewise, the right middle frontal gyrus was found to be active in the semantic processing of attributes of words related to living things in a study by Cappa et al. (1998b). These results are consistent with the lesion data reported in patients who suffered from HSE and developed a category specific deficit for living things (Wilson, 1997; Barbarotto et al., 1996, patients LF, FI and FA; De Renzi and Lucchelli, 1994). However, Farah et al. (1989) described a brain injured patient with a category specific deficit for living things whose inferior frontal lesion was localised in the right hemisphere, more in accordance with Cappa et al. (1998b) findings than with Martin et al. (1996).

Furthermore, Mummery et al. (1996) found another area of activation related to animals in the right inferior parietal regions. However, this finding is not supported by any evidence from lesion data related to patients with category specific deficit for living things.

Finally, in Mummery et al.'s (1998) study, the comparison between living things and man-made artefacts did not lead to significant differences as respect to the areas specifically involved in the processing of living things. The authors suggest that, in experiments where the stimuli are words, as in their investigation, the critical neural distinction within the semantic network has to be conceived in terms of attribute type differentiation, rather than on the basis of different semantic domains (see below), in contrast to the findings of Cappa et al. (1998b), where words were also used and a differential, though not extremely large, activation due to semantic category distinctions was observed.

Activation of the extrastriate areas for man-made artefacts

Visually complex artefacts, were found (Moore and Price, 1999) to activate the medial extrastriate cortex of the left hemisphere, a finding that was also reported by Perani et al. (1995) both for artefacts and animals, but in contrast to Martin et al. (1996) who observed selective activation of this area in relation to the presentation of animals. Moore and Price (1999) hypothesise that this region might be involved in the processing of visually complex stimuli, regardless the type of semantic category, and therefore an activation in the case of animals, as found by Martin et al. (1996), might be explained in terms of the greater visual complexity of animals, with respect to other types of living things and also tools, which usually have a very simple shape.

However, lesions to the occipital regions were reported in an HSE patient (Metha et al., 1992), and by Farah et al. (1991) in a patient with head injury, both showing a category specific deficit for living things. Therefore, these findings seem to provide support to Martin et al.'s (1996) and, though only partially, to Perani et al.'s (1995) results, rather than to Moore and Price's (1999) position.

Activation of temporal areas for man-made artefacts

Several findings were reported to show that the most activated regions in the case of tools were localised in the left posterior temporal areas. This result was observed in a few studies where the subjects were presented with pictorial stimuli, such as in a naming task (Martin et al., 1996; in Damasio et al. (1996) activation was specifically found in the left posterior middle and inferior temporal regions), and in two works by Mummery and colleagues, where subjects were involved either in a category fluency task (Mummery et al., 1996) or in semantic similarity judgements (Mummery et al., 1998), in both cases in response to a verbal input. In Mummery et al.'s (1998) view it is likely that if a preponderant influence in the processing of living things is devoted for visual analysis, a selective activation in response to living things might be observed only if stimuli are presented in a pictorial format, and not when words are used as stimuli, as they were in their study. However, the activation of the left posterior middle temporal gyrus by artefacts, might suggest that this area is critical for this semantic domain. Furthermore, in a study by Cappa et al. (1998b), requiring visual vs. functional/associative semantic judgements about words related to either living things and man-made artefacts, the left inferior temporal cortex and the left supra marginal gyrus were more active when the presentation involved tools words; further areas of activation were observed in the right superior temporal gyrus.

Mummery and colleagues support their conclusion by referring to single case studies of brain damaged patients who suffered from an extensive left middle cerebral artery stoke and showed a selective deficit affecting man-made artefacts associated to damage of this area (Gainotti et al., 1995; Hillis and Caramazza, 1991; Warrington and McCarthy, 1987). The activation of the left posterior temporal regions was also reported in response to visual confrontation naming and word-to-picture matching tasks by Moore and Price (1999): more specifically, these authors found an increased activation in the case of visually simple artefacts, such as tools, but not for multi-component artefacts, like vehicles. This same area was found to be active in tasks of action generation (Martin et al., 1995; Decety et al., 1997). This region lies just anterior to the areas active when movements are perceived, V6 and MT, (Corbetta et al., 1990; Zeki et al., 1991), and in Martin et al.'s (1996) view it might be involved in the storage of knowledge about patterns of visual motion associated to the use of objects. Therefore, the increase of activation in response to a variety of tasks involving tools and in action generation might suggest that the left posterior temporal regions are involved in the representation of action, because of a close link between actions and tools, which are highly manipulable objects with respect to other types of artefacts.

However, in a study by Laiacona et al. (1993a) damage to the left posterior temporal areas was associated to a selective deficit for living things in a patient, RG, who suffered from brain injury.

Activation of other areas for man-made artefacts

Tools were reported to activate the left lateral inferior frontal cortex and the pre-central frontal areas in Martin et al.'s (1996) study. Furthermore, the left premotor cortex, is also active when subjects imagine to grasp objects (Decety et al., 1994), and Martin and co-workers hypothesise that it might be involved in the storage of knowledge about how objects are used.

A further activation of frontal areas was also found by Perani et al. (1995), who found a left inferior frontal activation in the case of tools.

Some lesion data might support Perani and colleagues' finding about the frontal activation in the case of man-made artefacts (Hillis et al., 1990; Sacchett and Humphreys, 1992). However, in other lesion studies lesions to the frontal areas were associated to selective deficit for living things, again supporting Martin et al.'s (1996) view, both in HSE patients (Wilson, 1997; Barbarotto et al., 1996, patients LF, FI and FA; Silveri and Gainotti, 1988; Gainotti and Silveri, 1996; De Renzi and Lucchelli, 1994) and also in patients with other kinds of aetiologies (Farah et al., 1989; Laiacona et al., 1993a; Hillis and Caramazza, 1991; Samson et al., 1998). However, it has to be stressed that in many instances the lesion data concerning a frontal involvement are more incomplete than in the case of functional imaging findings; in fact, lesion studies often indicate only broadly the area which is damaged, without providing further information about the precise localisation of the lesion (anterior, inferior, middle, basal aspects etc.). Therefore, at least in the case of activation in the frontal areas, lesion data are not accurate enough to provide a clear support to the functional imaging findings.

Activation in response to differential semantic attributes

A small number of functional imaging researches devoted their attention to the different role of semantic attributes in category specificity. In a task of similarity judgements on triads of words or pictures, no selective effects were found for perceptual and associative features (Vandenberghe, Price, Wise, Josephs and Frackowiak, 1996). However, in another study Martin et al. (1995) required subjects to imagine the colour or the action associated to words or pictures of tools, and the perceptual task led to an activation in the ventral temporal lobe, which was bilateral in the case of pictures and left sided when words were used. Imagining functional (action) properties involved instead an enhanced activation in the left posterior middle temporal regions. However, these studies cannot disentangle the effects due to semantic class from those related to features types.

In three subsequent studies, this issue was addressed in more detail (Thompson-Schill et al., 1999; Mummery et al., 1998; Cappa et al., 1998b). Thompson-Schill et al. (1999) required subjects to perform a semantic judgement task about the visual and non-visual properties of both living things and man-made artefacts domains. The authors found that activity in the left fusiform gyrus was present for living things both in the case of visual and non-visual judgements. However, visual judgements activated this same area also in the case of man-made artefacts. Therefore, the authors stress the fundamental role of the left fusiform gyrus in the retrieval of visual knowledge in general. This result is in contrast with the findings of Cappa et al. (1998b) and Moore and Price (1999), where a right sided activation of the fusiform gyrus was found in response to living things. More specifically, Thompson-Shill and colleagues hypothesise the fundamental involvement of this region for the processing of living things (see also Perani et al., 1995), which, in the authors' view, rely more on this type of information than on other kinds of semantic properties. This result is therefore consistent with studies on HSE patients (Warrington and Shallice, 1984; Silveri and Gainotti, 1988, Gainotti and Silveri, 1996; Metha et al., 1992) and brain injury patients (Farah et al., 1989), who showed a category specific deficit for living things.

In Mummery et al.'s (1998) work, triads of written names of living things and man-made artefacts were presented to subjects for a similarity judgement task on the basis of perceptual (colour of the stimuli) and associative (typical location of items) attributes. In general, similarity judgements for both semantic category and attribute types activated extensively the left hemisphere, extending from the left temporal-occipital-parietal junction, through the infero-lateral temporal lobe, to the inferior frontal gyrus (see also below Cappa et al., 1998b): these data lead the authors to identify these as regions belonging to a common network devoted to the retrieval of general semantic knowledge. Their conclusion is in keeping with the findings of other studies which employed semantic tasks, regardless the type of stimuli or the tasks used (Vandenberghe et al., 1996; Martin et al., 1995; Warburton et al., 1996; Wise et al., 1991; Price et al., 1997). Furthermore, the observed temporal activation during the semantic task is consistent with data from patients with semantic dementia, who are typically damaged in the left anterior and infero-lateral temporal lobe (Hodges and Patterson, 1997; Hodges, Patterson, Oxbury and Funnell, 1992). The activation of the left inferior frontal areas, also reported by Petersen et al. (1988) and Vandenberghe et al. (1996) when subjects perform semantic tasks, is less easily interpretable in Mummery et al.'s (1998) opinion. However, Cappa et al. (1998b, see below) found foci of activation in the left inferior and superior frontal gyri. Moreover, this region is often damaged in HSE patients, who present broad semantic deficits, whereas a deficit of the knowledge of man-made artefacts can be associated to lesions of the left fronto-temporal areas (Gainotti et al., 1995). More specifically, a left inferior frontal damage was observed in HSE patients by Wilson (1997, patient CW); Barbarotto et al. (1996, patient LF); however, a right inferior frontal involvement was reported by Farah et al. (1991; 1996) in patients with brain injury.

When the differences regarding semantic attribute type (associative vs. perceptual) were examined, Mummery et al. (1998) found that the activation of the left temporo-occipital-parietal junction in associative judgements about location might involve in the authors' opinion mental imagery processes, and their results are compatible with Fletcher et al.'s (1995) findings, and partially in contrast to those of Cappa et al.'s (1998b), who found in a similar type of judgement a bilateral temporo-parietal activation. Furthermore, a selective activation was reported in the left antero-medial temporal cortex and caudate nucleus associated to judgements on the basis of colour. The involvement of caudate nucleus in colour naming was also reported by Price et al. (1996). Mummery and co-workers hypothesise that this area might be involved in the integration of different visual characteristics, being thus critical in the representation of stimuli which can be distinguished through the fine-grained analysis of visual features (see also a lesioning study of macaque monkeys by Gaffan, 1994). More specifically, location judgements for artefacts were associated to the activation of the left temporo-occipital-parietal junction, whereas in the case of living things an increased activation was observed bilaterally in the temporal-occipital-parietal junction, and the left middle frontal gyrus. However, no significant differences in activation were observed on the colour judgement task with respect to different semantic domains, at variance with the results by Cappa et al. (1998b) that will be described later in this section.

Despite the relevance of Mummery et al.'s (1998) study, it is difficult to perform a comparison with lesion data of patients with category specific deficits, even though impairments involving attribute type knowledge have been frequently described. The knowledge of visual properties has been reported to be selectively impaired in several studies of HSE patients (De Renzi and Lucchelli, 1994; Silveri and Gainotti, 1988; Sartori and Job, 1988; Sartori et al., 1993b; Moss et al., 1997; Ferreira et al., 1997; Metha et al., 1992) and of patients with other aetiologies (Basso et al., 1988; Forde et al., 1997; Farah et al., 1989; Coltheart et al., 1998). Their impairment of attribute knowledge, however, could not be simply ascribed to either location or colour information, as in Mummery et al.'s (1998) study, because the tasks used to evaluate the patients' knowledge usually involved a larger array of properties, both in the case of visual and functional-associative attributes. However, if one considers just visual properties, Mummery and colleagues (1998) indicated an increased activation in the left antero-medial temporal cortex, and Thompson-Schill et al. (1999) found that the left middle temporal gyrus and the left fusiform gyrus are critically involved in the processing of this type of semantic information. These findings are consistent with the peculiar pattern of deficit described by Coltheart et al. (1998) in a patient who had damage in the territory of the left middle cerebral artery and showed the selective impairment of visual attributes after a stroke, without any evidence of category specific deficits. Moreover, Perani et al. (1995) found activation in response to animals in the left fusiform and lingual gyri, and Moore and Price (1999) and Cappa et al. (1998b) in the right fusiform gyrus. Therefore, the middle temporal areas, and perhaps the fusiform gyri, might be relevant in subserving a system devoted to the processing of visual properties and perhaps of living things, a class of stimuli which is held to be extremely dependent on the analysis of sensory-visual information (Warrington and Shallice, 1984; Farah and McClelland, 1991).

In a further relevant study, the relationship between semantic categories and attribute processing was further investigated (Cappa et al., 1998b). Subjects were required to perform semantic judgements according to four different conditions implying the presentation of words: (a) decision about the relative length (long/short) of the tail of an animal with respect to its body (living things/visual knowledge condition); (b) decision about the place (Italy or not) where an animal typically lives (living things/associative knowledge condition); (c) decision regarding the relative length/width (longer than wider or vice versa) of an object (artefacts/visual knowledge condition); (d) decision related the typical use (kitchen tool or not) of an object. A general effect, ascribed to lexical semantic access, was first found when the four conditions were combined: Activations were observed in the left inferior and superior frontal gyri, along with bilateral activations in the parieto-occipital junction and the posterior cingulate. These data are in keeping with the findings of Vandenberghe et al. (1996) and Fletcher et al. (1995), and interpreted as evidence of areas involved in the semantic processing (prefrontal cortex and parieto-occipito-temporal junction), and regions subserving attentional processing (posterior cingulate). These results are also supported by lesion data related to HSE patients with a deficit for living things (Wilson, 1997; Barbarotto et al., 1996). The analysis of visual vs. associative knowledge conditions highlighted the bilateral activation of the inferior temporal, inferior parietal and prefrontal regions for visual judgements; associative judgements were instead associated to the activation of temporo-parietal areas bilaterally. These findings seems to support Gainotti and Silveri (1996) and Gainotti et al. (1991) position, as far as visual processing is concerned, and Mummery et al (1998) in relation to associative knowledge. In Cappa et al.'s (1998b) work, each condition was then examined separately: the visual judgements for living things led to bilateral activation of the prefrontal cortex and the posterior cingulate cortex, along with a right sided focus of activity in the parieto-occipital junction. In the case of visual judgements related to artefacts, left activation in the dorsolateral frontal cortex and in the inferior and middle temporal cortex was found. The associative judgements referring to living things were associated to bilateral activation in the parieto-occipital junction and the posterior cingulate cortex: further foci of activations were observed in the left medial frontal gyrus. Associative judgements for artefacts led to the activation of the inferior frontal gyrus and the parieto-occipital junction on the left hemisphere; moreover, bilateral activation was found in the posterior cingulate cortex. In the authors view, in this study semantic category differences were found to be less evident than in other functional imaging studies, probably due to the use of a verbal input with respect to the usual pictorial stimuli. However, the finding of a prevalent bilateral involvement during living things processing and of a left sided activation with respect to artefacts presentation is in keeping with lesion studies (Gainotti and Silveri, 1996; Saffran and Schwartz, 1994; Tranel et al., 1997).

Table 3: Areas found to be active in functional imaging studies of category specific effects

	Living things	**Artefacts**
L mid. extrastriate	Martin et al., 1996 Moore & Price, 1999	Moore & Price, 1999
R mid. extrastriate	Perani et al., 1995	
L inf. temporal	Damasio et al., 1996	Cappa et al., 1998b
R sup. temporal		Cappa et al., 1998b
L supramarginal g.		Cappa et al., 1998b
L post. temporal		Damasio et al., 1996 Martin et al., 1996 Mummery et al., 1996 Moore & Price, 1999 Mummery et al., 1998
L inf. frontal		Perani et al., 1995
L lat. inf. frontal		Martin et al., 1996
L premotor		Martin et al., 1996
R mid. frontal	Cappa et al., 1998b	
L ant. temporal	Moore & Price, 1999 Mummery et al., 1996	
R ant. temporal	Mummery et al., 1996	
R post. mid. temporal	Moore & Price, 1999	
L mid. temporal	Thompson-Schill et al., 1999	
L fusiform g.	Perani et al., 1995 Thompson-Schill et al., 1999	
R fusiform g.	Moore & Price, 1999 Cappa et al., 1998b	
L lingual g.	Perani et al., 1995	
R inf. parietal	Mummery et al., 1996	

L= Left; R= Right; bil= Bilateral; ant.= Anterior; post.= Posterior; mid.= Middle; inf.= Inferior; sup.= Superior

As can be drawn from the brief review of the literature on the neural correlates of category specificity, despite certain variability, some consistent areas seem to be more frequently involved in response to either living things or man-made artefacts (see table 3). In the case of living things, a large region was found to be active in different studies: the left temporal lobe, particularly in the anterior medial parts, seems to be critically involved in the processing of visual properties and living things stimuli. The presentation of man-made artefacts items seems to be instead frequently associated to the activation of the left posterior temporal lobe.

In functional imaging studies, however, substantial differences as respect to the nature of the stimuli, the type of input modality, and the tasks used are evident. However, careful attention to both experimental paradigms and stimuli adoption in functional imaging studies may lead in the future to a better understanding of this phenomenon. As yet, general conclusions are difficult to be drawn as regards to the neural implementation in the brain of category-specific effects, although some of the data are consistent to the lesion studies presented in sections 3.4.1.1. and 3.4.1.2. In effect, the comparison to lesion data is often difficult to perform because the areas damaged in patients are usually very large, and highly overlapping to the specific regions indicated to be critical by functional imaging studies. However, the relevance of functional imaging studies is posited, not only as respects to a valuable source of data regarding cerebral areas involved in the processing of different semantic domains, but also, and more importantly, as a further source of evidences in support to different cognitive theoretical account.

In the next section (3.4.3) an attempt to draw some conclusions about category specific phenomena from both lesion data and functional imaging studies will be performed.

3.4.3 Summary of lesion and imaging studies

Both HSE patients and patients who suffered from other pathological diseases, who showed a category specific deficits for living things relative to man-made artefacts, were found to have extensive damage involving either the left or both the temporal lobes. The lesion pattern (see table 2 for lesion data in HSE patients) commonly affects the lateral, medial, inferior and basal areas of the temporal lobe. The damage is frequently more prominent anteriorly, while posterior areas are more rarely involved. The limbic system is also frequently affected on the left side or bilaterally both in HSE and non-HSE patients, and damage often includes hippocampus and parahippocampus; in HSE patients lesions to the caudate, uncus and amigdala were also reported, though less regularly. Lesions of the inferior, medial and basal regions of frontal lobes are also commonly observed in HSE patients, but far less frequently in patients with other aetiologies. Finally, in patients with HSE the temporo-occipital areas are sometimes found to be affected, particularly in the lateral and medial parts; also non-HSE patients show in some instances bilateral damage of the medial parts of the occipital lobes.

Patients who suffered from pathological diseases different from HSE were also shown to present a category specific deficit for man-made artefacts relative to living things. In the majority of the cases damage to the left hemisphere was reported. The areas involved, however, were widely various: temporal, temporo-parietal or fronto-parietal lesions have been described. Furthermore, in some of the cases, the temporo-occipito-parietal junction, the temporo-occipital areas, the inferior parietal lobule, and the basal ganglia were found to be compromised.

In functional imaging studies several areas have been reported to be associated to the presentation of living things stimuli. Firstly, the left middle extrastriate cortex was found to be active in response to animals. However, the same area was activated also by complex man-made artefacts. Therefore this region might be devoted to the processing of visually complex stimuli, regardless the semantic domain. In contrast, the left temporal lobe has been consistently reported to be involved in the processing of living things in many studies: in particular, the role of the left anterior middle temporal regions and of the fusiform gyri seems to be critical as respect to living entities. Moreover, these areas were found to be active also when an analysis of visual attributes was required to subjects, highlighting the possibility that these properties are deeply involved in the processing of living things, as proposed by Warrington and Shallice (1984) and Farah and McClelland (1991). Further results have been reported as regards to the left frontal lobe, which was reported to be activated by man-made artefacts in different studies. The left posterior middle and inferior temporal regions were instead frequently found to be active after presentation of man-made artefacts in several studies, leading to the hypothesis that this area might be selectively involved in the processing of man-made artefacts stimuli.

The data reported in the three previous sections (3.4.1.1, 3.4.1.2 and 3.4.2) offer therefore ground for a comparison of lesion and functional imaging findings. As shown in table 3, functional imaging studies of category specific effects often reported the involvement of the temporal lobe, particularly on the left side, both in response to living things and man-made artefacts. However, the left middle anterior temporal regions were often associated to the presentation of living things stimuli, and this finding seems to be consistent with lesion data from both HSE and non-HSE patients. It has to be stressed, however, that in the case of lesion data, the temporal lobe is often largely damaged, with the involvement of the lateral, inferior, basal and middle aspects, whereas in functional imaging studies only the medial parts were reported to be active. Consistent findings were also reported as far as the frontal lobe is concerned, although in patients lesions usually affected bilaterally the medial basal and inferior parts, whereas in functional imaging studies a selective left sided activation of the frontal lobe was often reported. Moreover, both in lesion and functional imaging studies a middle temporo-occipital involvement was observed, both as respect to living things and man-made artefacts. However, the selective involvement of limbic structures has been described in just one functional imaging study (Cappa et al., 1998b), while this is a very common damage in patients with category specific deficit for living things.

In functional imaging studies the left posterior temporal areas were shown to be most frequently activated by man-made artefacts. However, patients often showed more extensive lesions, affecting temporal, parietal, frontal and occipital lobes, in different combinations. Therefore, although some consistency can be observed as far as the neuroanatomical substrate of living things processing is considered in both types of researches, lesion studies of patients with a selective deficit for man-made artefacts highlight the involvement of too a wide range of areas to draw a clear comparison with functional imaging data.

However, the indication of the critical involvement of the left posterior temporal lobe in response to artefacts stimuli found in functional imaging studies might be very useful in addressing future investigations of category specific deficits, strongly suggesting that highly precise descriptions of the lesion pattern shown by patients are needed in order to achieve a comprehensive picture of the neural implementation of man-made artefacts (but also of living things!) in the brain. This is still more critical, if one considers that in functional imaging studies a strictly related issue, that of action representation with respect to tool use, has been addressed in detail, while in the studies of category specific deficits regarding man-made artefacts the role of action knowledge has never been thoroughly examined so far.

3.5 Main predictions from relevant theories

The survey of the wide array of theoretical accounts proposed by various authors, described in the preceding parts of this chapter (sections 3.3.1, 3.3.2 and 3.3.3), directly suggests that divergent predictions follow from these positions. The most influential ones will be discussed here.

On Warrington and co-workers' (Warrington and Shallice, 1984; Warrington and McCarthy, 1983; 1987) view, "sensory-quality" categories prominently rely on sensory processing, being, in contrast, much less dependent on functional properties. On this ground, living things and other semantic classes, such as "mass" kinds, whose discrimination is thought to be highly dependent on an analysis of their colour, texture, and, in general, on their surface characteristics, should behave in a similar fashion across tasks. At variance, man-made artefacts are held to be differentiated in terms of their function, and only to a minimal extent on the basis of their sensory attributes. The only perceptual characteristic which might play some role on artefacts distinction may be that of shape, being closely related to the function an object is called to accomplish. Therefore, man-made artefacts are expected to show a clearly different behaviour with respect to "sensory quality" categories. Moreover, the relative weight of sensory vs. functional characteristics should be differentially highlighted as far as sensory quality categories and man-made artefacts are concerned. Therefore, from a featural perspective, a patient showing a category specific deficit affecting sensory quality categories should demonstrate an impoverished knowledge of sensory attributes in contrast to a relatively preserved knowledge of semantic functional information.

The proposal put forward by Caramazza and colleagues (Caramazza et al., 1990; Rapp et al., 1993; Hillis et al., 1995) with respect to the OUCH model, can be tested as regards to only one of its assumptions: the authors hold that highly intercorrelated bunches of features encompass different semantic categories. However, the intercorrelation of both sensory and functional properties makes impossible the observation of a selective damage to either one of the two types of semantic properties. Although on the OUCH's view any category specific deficit can virtually arise, depending on the density and location of intercorrelated features within the semantic space, so that a semantic deficit affecting specifically living things and "mass" items, in contrast to the sparing of man-made artefacts, can be accounted by the OUCH assumptions, a differential impairment of sensory vs. functional knowledge should not be observed, regardless the category which is shown to be damaged in a patient.

Caramazza and Shelton's (1998) much stronger assumptions, lead however to a complex range of predictions to be tested. Firstly, on their account, evolutionary pressures lead the organisation of the semantic system to arise in a categorical fashion, where animals, plants and perhaps foods are independently represented with respect to man-made artefacts. Thus, a category specific deficit should simply lead to either a selective impairment affecting living things (and foods) or man-made artefacts. Therefore, a fundamental prediction following from Caramazza and Shelton's theory can be tested: from the authors' assumption of the categorical organisation of the semantic memory system into living things, on the one hand, and man-made artefacts, on the other, it follows that <u>other</u> semantic categories, different from those indicated by the authors, should not be impaired <u>along with</u> either one of the two main semantic classes. However, a main point has to be clarified here: in the authors' opinion, a deficit for living things can be found along with an impairment with foods, because both categories reflect the constraints of the same evolutionary pressures. The same association of deficits, however, would be explained by Warrington and Shallice (1984) on the ground that both living things and foods are categories whose representation posits on a similar cross-categorical processing, highly dependent on the analysis of sensory quality properties. Therefore, if a deficit for living things is observed along with an impairment of <u>other</u> semantic categories, which, contrary to Caramazza and Shelton's assumption, have <u>no</u> evolutionary relevance, <u>but</u>, in keeping with Warrington and Shallice's position, are held to be processed mainly in terms of sensory quality properties, the contrasting predictions of these two groups of theorists will be disentangled. In the light of the above consideration, patients' performance with respect to a semantic category such as <u>materials</u>, should be critical in order to differentiate the two theories, since materials are not edible things like, as argued by Caramazza and Shelton, animals, plants and foods; however, materials are generally identified and distinguished from one another through the analysis of their colour, texture, roughness, etc., that can be considered, in Warrington and Shallice's view, sensory quality properties.

A second consideration can be drawn from Caramazza and Shelton's theoretical proposal. In the authors' opinion, the properties which are held to be involved in the ontological development of categorical distinctions within the semantic memory system, though they are not considered key features once the structure of the system is achieved, are the internal organs and the intentionality of motion in the limited case of animate kinds, the function in the case of artefacts. Therefore, in Caramazza and Shelton's view, no critical role is attributed to sensory features as far as living things are concerned. The opposite claim is instead put forward by Warrington and Shallice (1984) as regards to the fundamental role of sensory features in the processing of the living things category. Consequently, if sensory knowledge *per se* can be shown to have a role in the emergence of both a category specific deficit for living things and other sensory quality categories such as edible substances and non edible materials, this will challenge Caramazza and Shelton's āssumptions and provide instead support to Warrington and Shallice's position.

The major claim from Gonnerman and co-workers (Gonnerman et al., 1997; Devlin et al., 1998) is concerned with the strict association of category specific deficit to the severity of brain damage. Milder impairments to the semantic memory system will lead to a better performance with respect to living things as opposed to artefacts. At more severe degrees of impairment the living things deficit emerges relative to man-made artefacts. Therefore, if a group of patients is closely matched as regards to their performance on man-made artefacts, a differential degree of impairments should not be observed with respect to living things in the same patient group.

De Renzi and Lucchelli's (1994) claim of the existence of form-function relations as a critical characteristic of the man-made artefacts category lead to the hypothesis that in category-specific deficits for living things, patients' artefacts knowledge will be supported by the fact that this type of relationship is intact within the semantic memory system. In contrast, living things are principally represented in terms of visual sensory properties, while form-function relations do not characterise the living things representation. This last assumption implies that patients with category specific deficits for living things will show an impairment regarding the visual properties of the affected category; furthermore, their performance will not benefit from form-function information associated to living things, since in the authors' view this type of semantic relation do not exist in the case of this category. However, if the existence of form-function relations (i.e. of the type described by Tyler and co-workers) can be shown to be preserved as far as living things are concerned, this will challenge De Renzi and Lucchelli's position.

In the view of Tyler and colleagues (Tyler and Moss, 1997; Moss et al., 1996; Tyler et al., in press), form-function relations are held to characterise man-made artefacts and living things as well. Distinctive perceptual features are connected to distinctive functional properties in the artefacts case; shared perceptual features are associated to shared biological functions in the case of living things. Therefore Tyler and co-workers hypothesise that a living things deficit should be accompanied by a loss of distinctive perceptual properties which are less strongly intercorrelated and therefore more vulnerable to loss than biological function information. Therefore, a widespread loss of perceptual features should not be observed in the case of a category specific deficit for living things: a damage to perceptual knowledge related to living things should in fact be linked to the loss of the distinctive perceptual features and not of the shared, much more interconnected, perceptual properties. Finally, no advantage should be observed for either shared or distinctive features in the case of artefacts.

Although the predictions following from the last two theories are not concerned with the major purpose of the present study, both will be addressed in a preliminary investigation related to the aim of re-framing the meaning of functional and sensory information. The position is proposed here that the two concepts carry other, and probably independent, types of semantic information. On the one hand, it is acknowledged, as in Tyler and co-workers' view, that sensory features imply functional aspects that will be therefore examined in the present work. On the other hand, functional attributes are certainly connected to the use of objects, and in this sense the form, shape, of an item is thought to be fundamental in suggesting the function of that object (Tyler and Moss, 1997; De Renzi and Lucchelli, 1994). However, a further issue, will be addressed as respect to both types of semantic properties. On the ground of Buxbaum and Saffran's (1998) findings, the knowledge of the action (manipulability) related to the use of an item can be dissociated from that connected to the function of the same object. In fact, Buxbaum and Saffran found that in a group of aphasic patients with apraxia, action (or manipulability) information was more impaired with respect to the pure notion of function. Therefore, in the present work the attempt will be made of disentangling functional from action knowledge, both in the case of sensory and functional features. This new perspective therefore represents a further step in examining the complex range of meanings characterising these two semantic properties, and aims to redefine the positions on attribute knowledge held by De Renzi and Lucchelli and by Tyler and co-workers.

Chapter 4: Case report

4.1 Patients' description

A group of six patients admitted to the S. Bortolo Hospital in Vicenza, Italy, were examined throughout a period of 2 years, from March 1997 to March 1999 (MU's assessment lasted until May 2000). All had a diagnosis of encephalitis of probable herpes simplex viral origin, contracted in the preceding four years (see table 4 for a synoptic picture of their personal data and lesion sites). They were assessed on a series of tasks involving different modalities and different types of stimuli, on perceptual tasks and other intermodal tasks, tapping the relations between visual and verbal concept attributes. Tables 5 and 6 provide a general outline of the performance of the patients' group on a series of tasks involving general intelligence, attentional abilities, memory functions and language skills (table 5), and visuo-perceptual and visuo-spatial abilities (table 6).

Table 4: Patients' clinical description

Patient	Age	Education	CT Scan	MRI scan
MU	30	13	R Temporal, Bilateral Frontal	Bilateral Temporal infero/medial parts, Bilateral Frontal medial parts, R Occipital medial part
Bai	50	5	------------------	Negative
Bar	49	5	L Temporo-Parietal	L insula and surroundings
Cal	59	8	Negative	L Frontal
Mio	75	3	L Temporal, Bilateral Frontal	L Temporal, L insula, Bilateral Frontal paramedian areas
Sar	56	5	Bilateral Frontal basal parts, R Temporal	R Fronto-Temporal

4.2 Neurological examination

4.2.1 Case descriptions

4.2.1.1 Case 1

MU is a plumber who was aged 30, with 13 years of schooling. At the end of September 1994 the patient became feverish and, after developing mental confusion, he went into a vigil coma state: he was admitted to different hospitals, with a diagnosis of probable herpetic encephalitis. He was feverish for more than one month, and because of his coma state he needed ventilation for about two weeks. He also had an hemiparesis affecting the left part of the face and the left hand. The levels of lymphocytes and proteins in the CSF were enhanced, as well as the level of neutrophyls, although the percentage of glucose was normal. He started to show signs of recovery only after the treatment with Acyclovir, which started more than a week after the first appearance of the symptoms, and, probably for this reason, no signs of HSE virus were found in an analysis of the CSF performed two weeks after the admission to the hospital. He came out of the vigil coma state only in the following April 1995, when a first neuropsychological assessment became possible (at S. Camillo, Venice).

The first EEG was characterised by signs of severe diffuse cerebral damage, with diffuse activity, characterised by theta and delta waves; this is typical of viral encephalitis. After 2 months, his EEG showed some improvements, with the recovery of the basal rhythm in the left hemisphere, while in the right hemisphere signs of damage were still present. Subsequent EEGs showed altered signals in left posterior areas and in the right hemisphere, and an unstable background activity.

The first CT scan showed severe cortical damage, compatible with HSE, more evident in the right hemisphere, with an involvement of the external capsula, and another hypodensity in the left peri-Sylvian areas. In a subsequent CT scan ventricular enlargement and scattered hypodensities were observed in the right temporal lobe; in addition there were small areas of hypodensity in both frontal lobes, near the corpus callosum, and also in the superior part of the left parietal lobe. The MRI scan (figures 2 and 3) showed diffuse damage involving both temporal lobes, the medial portions of frontal lobes and the medial aspects of the right occipital lobe.

The pattern of cerebral damage observed in MU is entirely consistent with both lesion data from other HSE patients (see section 3.4.1.1 and table 2) and the findings related to the activation sites associated to the presentation of living things found in functional imaging studies (section 3.4.2 and table 3).

4.2.1.2 Case 2

BAI is a 50 years old female housewife, with 5 years of education. The patient, feverish, confused and with signs of speech disorders was admitted to the hospital in January 1997. After four days she recovered from the fever and in ten days she became more collaborative and less confused. On the basis of a series of clinical and neuroradiological evidences, including the analysis of the CSF (high level of glucose, lymphocytes and proteins) a diagnosis of HSE was made, and the patient was treated for a period of ten days with Acyclovir. The initial PCR exam, carried out 3-4 days from the appearance of the behavioural symptoms, showed values above the normal range, while a second one, performed ten days later, after administration of Acyclovir, did not find signs of presence of the virus.

An EEG performed after her entering the hospital showed altered bitemporal signals, characterised by diffuse theta and delta activity typical of a viral encephalitis, but this pattern of activity slowly became normal. However, the MRI scan was normal, with no signs of encephalic or stems lesions.

4.2.1.3 Case 3

BAR is a turkey breeder 49 years old with 5 years of schooling. He was admitted in May 1996 to the hospital, feverish and highly anomic; a diagnosis of meningo-encephalitis, probably of herpetic origin was made; he was treated for 12 days with Acyclovir after the analysis of cerebro-spinal liquor with PCR, which was positive for HSE-1 virus. The CSF also showed an enhanced level of proteins and lymphocytes and neutrophyls, while the level of glucose remained stable. An EEG performed in June 1996 showed that alpha activity was more organised than in the first EEG made in May 1996. Still present were anomalies, characterised by slow, degraded and sharpened waves in the left parieto-temporal areas, a pattern typical of viral encephalitis, with a tendency to propagate toward the anterior homolateral and controlateral regions. The EEG performed one year later, showed basal alpha activity which was slightly irregular in bilateral parieto-occipital regions. There was also a little slowing in basal theta activity localised in bilateral parieto-temporal areas. The CT scan, performed six days after admission to the hospital, showed evidence of a localised necrosis in the left temporo-parietal area. An MRI scan performed in 1998 showed an extensive damage affecting the left insula and its surroundings. The left temporal horn was also found to be more enlarged than the controlateral one. The pattern of lesions was ascribed to herpes encephalitis.

4.2.1.4 Case 4

CAL is aged 59 and has 8 years of education; before his illness he was an employee in a council office. At the admission to the hospital in October 1996 he was feverish and confused. A diagnosis of encephalitis of probable herpetic origin was made, and he was treated with Acyclovir, showing a rapid recovery after its administration. Unfortunately, PCR was not performed, and the viral origin of his illness was not clear from other cytological exams.

An EEG, performed after the admission to the hospital, showed diffuse altered encephalic signals for theta and delta waves, along with other more regular but slow rhythms, in fronto-bilateral areas, principally in the right side, considered compatible with viral encephalitis. An EEG performed 2 months later showed resting activity characterised by a basal bilateral rhythm of 10 Hz, considered within the limits and a clear sign of recovery from the acute phase of the illness. CT scan was negative. The MRI scan showed a lesion localised in the left frontal lobe, at the boundaries between cortical and subcortical layers.

4.2.1.5 Case 5

MIO is a 75 years old housekeeper, with 3 years of schooling. The patient was admitted to the hospital at the end of April 1996. She was feverish, highly confused, and showed signs of aphasia in verbal production. A diagnosis of HSE was made on the basis of a series of clinical and neuroradiological exams. The CSF showed an enhanced level of lymphocytes and proteins, whereas the percentage of glucose in cerebro-spinal fluid was normal. The patient was treated successfully with Acyclovir. The clinical examinations for the presence of herpes simplex virus were only performed about one month later, in a subsequent admission to the same hospital where no signs of HS virus were observed. Her EEG was characterised by low voltage activity, localised prominently in the left temporal lobe, which is compatible with herpes encephalitis. Both the CT scan and the MRI scans, performed during the first admission, showed lesions affecting both the left temporal and frontal lobes. In addition, the MRI scan showed damages to the left insula and in a small region localised in the left frontal paramedian area: small areas of altered signal, presumably of ischaemic type, were also noted in the white matter.

4.2.1.6 Case 6

SAR is a 56 years old man who had 5 years of schooling. He had a number of different jobs, having been a farmer, then a workman, and is now retired. He was admitted to hospital in January 1994 following an encephalitis of probable herpetic origin. He was confused and feverish. The analysis of the CSF showed normal levels of glucose and neutrophyls, whereas proteins and lymphocytes were above the normal range. Although cytological exams did not exhaustively support the diagnosis of encephalitis due to herpes simplex virus, he was treated successfully with Acyclovir.

An EEG performed in 1997 showed focal right fronto-temporal signs and epileptic-like anomalies within the same area, typical of viral encephalitis; a later EEG showed the disappearance of the epilectogenic focus in right fronto-temporal areas. A CT scan revealed the presence of an area of hypodensity mainly in the fronto-basal and right temporal regions, compatible with HSE. The right lateral ventricle was larger than the controlateral one. A densitometric examination of the temporal parenchymal tissue gave normal results, with the exception of the presence of a right frontal hypodensity, particularly in subcortical sites. An MRI performed in 1998 showed a lesion in the right fronto-temporal region, which extends to the cingulate gyrus: in the periphery of this region, there is a thinning of cortical layers, also involving parts of the left frontal circumvolutions and the periventricular white matter of both frontal lobes. The degeneration of the white matter also extends posteriorly, into the right parietal regions. The ventricular system is much larger on the right side than the left, and the corpus callosum is thinner and more irregular than in normal controls.

4.3 Neuropsychological assessment

4.3.1 Case descriptions

4.3.1.1 Case 1

When MU firstly underwent neuropsychological assessment (see table 5), he was only administered some subtests of the WAIS Performance IQ, on which he was at the lower limit for normal controls, with the exception of object assembly, where he had a defective performance . On the Elithorn's Perceptual Maze test, however, he was severely impaired, although on Raven's Progressive Coloured Matrices he was within the normal range. However, both his categorical and verbal (FAS) fluencies were severely defective. His verbal reasoning was also impaired. In an attentional task (Visual Search) he was below normal limits, whereas he was normal with both versions of the Trial Making test. On the Weschler Memory Scale he was perfectly oriented, and performed within normal limits on the digit span forward subtest; however, he was clinically amnesic and severely impaired in all the other subtests (information, mental control, logic memory, learning paired associates and digit span backward). Corsi's span was also unimpaired. On language tests, a MU's verbal comprehension task (Token Test) was only mildly impaired. Since his naming ability was the aim of the present investigation, findings on naming tasks will be discussed in the experimental section.

On an initial examination his spontaneous speech was poor both for oral and written production, and a largely stereotyped oral production was observed. He had also abundant scialorrhea and serious problems in verbal articulation: for this reason his naming abilities were initially assessed using little plastic tag with capital letters of the alphabet printed on one side. After the first test with this procedure, MU always asked for these letters while being examined, even in tasks which did not required written answers, and kept reordering these letters alphabetically for the entire time of each testing session, as an acquired stereotyped behaviour. Later, when asked to name pictures of famous people, he was completely unable to perform the task, and an informal examination demonstrated a severe prosopagnosia, which included some of his relatives, but which later disappeared. By the end of testing he could recognise relatives and some of his friends, but he was still strongly impaired in recognising pictures of famous people and faces of persons met after his illness.

MU showed an impairment in certain clinical perceptual tasks such as the Street Completion Test; therefore, in order to investigate his performance on visual perceptual tasks more comprehensively, he was administered with the VOSP battery and some subtests of the BORB battery (see table 6). He was normal in all the BORB subtests except for the object decision tasks, but he had a defective performance on the Silhouettes, Progressive Silhouettes, Object Decision and Incomplete Letters subtests of the VOSP battery. As far as the Silhouettes test is concerned, it is important to note that MU did not show any difference between living and man-made artefact stimuli on this specific task (2/15 with living and 3/15 with man-made artefacts).

The possibility that the set of stimuli used in these subtests of the VOSP was too complex in the case of MU needs to be taken into account. On the Object Decision, Silhouettes and Progressive Silhouettes tests stimuli are blackened and distorted, in order to increase task difficulty. It is therefore possible that MU was impaired on these subtests because of a lack of details in the stimuli. It will be seen in the experimental section that MU's performance on VOSP subtests was, at least partially, influenced by manipulations other than the blackening of pictures, such as stimulus rotation and distortion (see the naming of Black Silhouettes). Colour perception was also examined and the performance of MU was slightly impaired being below that of normal controls of his age both in colour naming and identification. He could identify primary colours correctly but had some problems in naming colours such as "rose".

The characteristic initial symptoms and the EEG pattern and the cerebral areas mostly affected by the infection by patient MU led to the conclusion that an encephalitis of probable herpes origin would be the probable cause of his neurological damage.

4.3.1.2 Case 2

Her neuropsychological assessment (see table 5) was carried out starting in April 1997. BAI showed an unimpaired performance on the WAIS Performance IQ subtests. However, on other general intelligence tests she was below normal limits. In attentional tests her performance was relatively preserved, with the exception of a problem in the Trail Making B test. She was clinical amnesic and on the Weschler Memory Scale she was normal in orientation, mental control and digit span forward, but had deficits in information, learning paired associates, logic memory and digit span backward. Long term memory was just within limits for normal controls. Her spontaneous speech was fluent and well articulated, with minimal word finding problems, while her verbal comprehension was mildly defective. Her performance on naming tasks will be discussed below. In visual perceptual tasks (see table 6) she had normal scores, with the exception of the cube analysis subtest of the VOSP, and in a series of subtest of colour perception she was perfect both in colour naming and identification.

The initial PCR reading, the positive effect of Acyclovir and the initial EEG were all compatible with a diagnosis of herpes simplex virus encephalitis.

4.3.1.3 Case 3

In general intelligence functions (see table 5) BAR was generally average, and his performance in some WAIS subtests was normal. On attentional tasks, BAR showed a generalised impairment. Verbal reasoning was moderately impaired, and both his verbal and categorical fluency was also poor. When assessed on memory tests (see table 5), he was extremely impaired on some subtests of the Weschler Memory Scale (information, orientation, logic memory, learning paired associates, digit span backward), apart from the mental control and digit span forward subtests; in addition, his visuo-spatial span was severely impaired. His long-term memory performance was generally defective. Language was initially assessed with the AAT battery (April 1997), and showed poor production and comprehension; writing skills were preserved. A mild improvement was observed later in verbal comprehension. In the following months he recovered his speech abilities almost completely, with the exception of word finding problems in spontaneous production and, principally, in naming tasks, which will be described later in the paper. His visual perceptual abilities (see table 6) were initially affected severely. Later (September 1997) when he was examined with the VOSP battery, he was average, while with the BORB battery he showed a mild deficit in the easy version of the object decision test. When BAR was examined with some of the subtests of a battery for colour perception he was only 50% correct both in naming and identifying colours.

From the positive PCR exam for HSE virus type 1 and the neurological evidences, patient BAR was diagnosed as having suffered from an episode of encephalitis due to herpes simplex.

4.3.1.4 Case 4

CAL had a medium performance in some WAIS subtests; however, in some general intelligence tasks (see table 5) he was well within the normal range for his age and education. Both his verbal and categorical fluencies were in the normal range. His ability to perform a visual search and other attentional tests was generally well preserved. Verbal reasoning was normal. When memory functions were assessed, his short term memory was just within average. In the Weschler Memory Scale he showed some problems in orientation and information, and he couldn't also learn paired associates. He was anyway just within the normal range in story recall. His spontaneous language production was good, and, although he showed initial difficulties in the Token Test, his comprehension skills recovered quickly. As for the other patients, his naming abilities will be discussed later in the article. In perceptual tests (see table 6) CAL was within normal limits in the Benton's Line Orientation Judgement and in the Benton's Face Recognition test, but showed a severely impaired performance in the Hooper Visual Organization test and in the Street's Visual Completion test ; in the VOSP battery CAL was flawless on the majority of tasks, with the exception of Silhouettes and Object Decision tasks. In the BORB subtests, CAL was below normal controls only in the two versions of the Object Decision tasks (hard version 17/32; easy version 22/32). He showed an impairment in naming colours, but no deficits in colour identification.

The typical onset of his disease, the prompt recovery after Acyclovir treatment, the pattern shown by the first EEG and the lesion site demonstrated by the MRI were considered compatible with the diagnosis of probable encephalitis of herpes viral origin.

4.3.1.5 Case 5

MIO scored well within normal limits in tests of general intelligence, and was normal in the WAIS subtests administered to her (see table 5); both verbal and categorical fluency were within the normal limits when scores were corrected by age and education. Her performance on the Weschler Memory Scale subtests was generally defective, except in Digit Span forward; MIO's long term memory was severely defective. In attentional tests she was highly defective, but she was still able to perform a visual search task. MIO showed good spontaneous oral production; with the AAT battery, word and sentence comprehension was mildly impaired, both in oral and written presentation. She could also repeat, write and read without difficulties. When her verbal comprehension was assessed with the Token Test she was unimpaired. Her most evident problem was observed in naming tasks. Her performance in naming tasks will be discussed more thoroughly in the experimental section. She was also completely defective in naming pictures of famous people. Her perceptual functions (see table 6) were examined through the VOSP battery, with an impaired performance on the Silhouettes and Progressive Silhouettes subtests; however, her performance was unimpaired in all the BORB subtests except for the Object Decision task. In a battery for colour perception her performance was impaired both in naming colours and in a colour identification task.

On the grounds of the pattern of neurological and clinical observations a diagnosis of herpes encephalitis was made for patient MIO.

4.3.1.6 Case 6

In general intelligence tests (see table 5), SAR was normal on the WAIS subtests and in both the Raven Progressive Coloured Matrices and the Elithorn's Perceptual Maze test he was well above average. However he showed some deficits in attentional functions. His ability to perform verbal reasoning was within normal limits, as was his verbal fluency and his categorical fluency. The assessment of memory functions (see table 5) showed that his short term memory was good with the exception of the Corsi's span and of the Digit Span Backwards of the Weschler Memory Scale; he performed normally on the other subtests of the WMS. His spontaneous speech was good and comprehension was also spared, when informally examined. His naming performance will be discussed in a later section. In general perceptual tests (see table 6) he showed a severe impairment; when more basic abilities were examined through the VOSP and the BORB batteries, he had a normal performance in all the subtests, except in the case of Position Discrimination of the VOSP, and in both versions of the Object Decision test of the BORB battery. In a series of subtests of colour perception, the patient was quite impaired in colour naming but perfect in colour identification.

On the ground of the neurological and clinical observations a diagnosis of herpes simplex virus encephalitis was considered probable in the case of patient SAR.

Table 5: General neuropsychological assessment

	MU	Bai	Bar	Cal	Mio	Sar
WAIS[1] ¥						
Picture Completion	10	14	14	9	14	7
Block Design	10	9	9	11	14	9
Picture Arrangement	8	11	12	8	12	13
Picture Assembly	7	10	19	6	13	7
Performance IQ	91	112	126	107	126	92
Elithorn's Perceptual Maze test[2] %	9.5**	11.75 *	16.55	18	15.75	18
Raven Progressive Coloured Matrices[3] &	31.5	18.5 *	36.25	30.5	41.5	30.5
Verbal Reasoning[2] &	30.25**	----	45.75*	55	24**	47.25
Verbal Fluency (FAS)[4] &	2.8**	51.3	26.3 *	28.8	24.4	24.8
Categorical Fluency[2] &	3.5**	17 -	11.5 *	12.25*	12	57
Visual Search[2] %	42.25 *	51	42.25 *	51.5	44	33.75 *
TRAIL MAKING[5] %						
Trail A	38"	45"	64" §	58"	240''§	63"§
Trail B	1'45"	with help	with help	135"	360''§	127"
WESCHLER MEMORY SCALE[6] ¥						
Information	2**	1**	2**	4**	2**	6
Orientation	5	5	3**	3**	3**	5
Mental Control	2**	6	6	9	2**	7
Logic Memory	0.5**	2.5**	0**	5.5	0**	7
Learning Paired Associates	7**	7**	5**	0**	3**	13
Digit Span forward	6.5	4.75	4.75	4.75	4.5	6
Digit Span backward	4*	3*	3*	3*	2**	4*
Word span[2] &	4.5	----	2.75**	3.75	3.5	4
Corsi's span[2] %	5.5	----	2.5**	4.75	4.25	3.75 *
Story Recall[2] &	2**	9.75	5.75*	10.3	1.25**	8.1
Token Test (AAT) (errors)[7] %	17©	11©	9©	16©	3®	3®

*% The scores are scaled by age, sex and education; & The scores are scaled by age and education; ¥ The scores are scaled by age; ** score 2sd below normal mean; *score <1sd below normal mean; § score below upper limits for the normal range; © mild level of impairment; ® normal performance; [1] Wechsler (1986); [2]Spinnler and Tognoni (1987); [3]Raven (1962); [4]Ghidoni, Poletti, Bondavalli (1995); [5]Giovagnoli, Del Pesce, Mascheroni, Simonelli, Laiacona, Capitani (1996); [6]Wechsler (1948); [7]Luzzatti, Willmes, Bisiacchi, De Bleser, Faglia, Mazzucchi, Taricco (1987); [7]Luzzatti C., Willmes K., Bisiacchi p., De Bleser R., Faglia L., Mazzucchi A., Taricco M. The Aachen Aphasia Test (AAT). Psychometric properties of the Italian version. Archivio di Psicologia, Neurologia e Psichiatria, 48, 4, 480-519, 1987.*

Table 6: The performance of the patients on visual perceptual tasks

	MU	Bai	Bar	Cal	Mio	Sar
Hooper Visual Organization test[1]@	10/30	----	16/30 §	13/30§	13/30§	10/30§
Street's Completion test[2] %	5 *	----	2.25 **	3**	6.75	4.75 *
Benton's Line Orientation Judgement[3] ¥	20	----	19	26	19	21§
Benton's Face Recognition test[4] &	25§	----	----	43	38§	35 §
BORB[5] @						
Foreshortened View	23/25	24/25	25/25	22/25	23/25	24/25
Minimal Features	24/25	25/25	25/25	24/25	24/25	23/25
Item Match	30/32	32/32	31/32	31/32	32/32	32/32
Object Decision (hard version)	16/32 **	27/32	27/32	17/32**	21/32 **	19/32 **
Object Decision (easy version)	16/32 **	30/32	28/32	22/32**	25/32 **	26/32 **
VOSP[6] ¥						
Screening test	20/20	20/20	19/20	20/20	20/20	20/20
Incomplete Letters	14/20 #	18/20	17/20	17/20	16/20	16/20
Silhouettes	5/30 #	20/30	22/30	11/30#	4/30 #	16/30
Object Decision	14/20 #	18/20	15/20	11/20#	17/20	18/20
Progressive Silhouettes	16 #	6	13	13	17 #	13
Dot Counting	10/10	10/10	10/10	10/10	10/10	9/10
Position Discrimination	19/20	20/20	19/20	20/20	19/20	15/20 #
Number Location	9/10	10/10	9/10	10/10	8/10	10/10
Cube Analysis	8/10	6/10 #	10/10	10/10	9/10	9/10
De Vreese et al. Test for colour perception[7] %						
Colour Naming	8.2 *	9.7	5.3 **	7.4**	5.7 **	7.5 **
Colour Identification	8.01 **	9.8	5.3 **	10.2	7.2 **	10.3

*% The scores are scaled by age, sex and education; & The scores are scaled by age and education; ¥ The scores are scaled by age; @ The scores are not scaled; ** score 2sd below normal mean; *score <1sd below normal mean; § score below range for normal controls; # score below 5%cut off score; [1]Hooper (1985); [2]Spinnler, Tognoni (1987); [3]Benton, Silvan, Hamsher, Varney, Spreen (1990); [4]Benton, Silvan, Hamsher, Varney, Spreen (1992); [5]Riddoch, Humphreys (1993); [6]Warrington, James (1991); [7]De Vreese, Faglioni, Agnetti (1994).*

4.4 Summary of neuropsychological deficits in HSE patients

In general, as described in table 5, patients' extensive neuropsychological examination showed that all patients had a normal or medium performance on the WAIS performance IQ. Patient MU was however at the lower limits for normal controls, and impaired on the Object Assembly subtest.

Their scores in general intelligence tests were quite varied, being BAI normal in all the tests but the Elithorn's Perceptual Maze and in the Raven Progressive Coloured Matrices tests, while CAL showed an impairment restricted to Categorical Fluency, MIO a deficit limited to the Verbal Reasoning test and SAR was worse than normal controls in the Visual Search test. In contrast, a general intelligence impairment affecting their performance in the majority of tests was observed in patient BAR, who demonstrated a sparing only in the Elithorn's Perceptual Maze and the Raven Progressive Coloured Matrices tests, and patient MU, who was found defective in every test with the exception of the Raven Progressive Coloured Matrices.

Attentional functions were observed to be generally impaired in patient BAR and MIO, while deficits were shown by patient BAI in the B version of the Trial Making test and SAR as regards to the A version. At variance, patients MU and CAL attentional skills were normal on both versions of the test.

All patients showed generalised deficits affecting memory, with some exceptions: BAI was normal only with respect to Orientation, Mental Control and Digit Span forward of the Weschler Memory Scale, and on Story Recall; BAR reached the normal standards on Mental Control and Digit Span forward of the Weschler Memory Scale, while MIO could normally perform on Digit Span forward, Word span and Corsi's span. Patient CAL showed an unaffected performance on Mental Control, Logic Memory and Digit Span forward of the Weschler Memory Scale, and was also found to be normal when tested with Word span, Corsi's span and Story Recall tests. Only patient SAR was minimally affected when his memory skills were probed: he had a defective performance restricted to Digit Span backward of the Weschler Memory Scale and to Corsi's span. A severe memory loss was also observed in MU's case, since he was clearly affected on Information, Mental Control, Logic Memory, Learning Paired Associates and Digit Span backward of the Weschler Memory Scale subtests, and also on the

Story Recall test.

Language comprehension was found to be spared only in MIO and SAR, while the other patients showed all a mild level of impairment.

A general assessment of patients visual perceptual skills (table 6) highlighted deficits on the Hooper Visual Organization test in patients BAR, CAL, MIO and SAR, on the Street's Completion test in patients BAR, CAL and SAR, on Benton's Face Recognition test in patients MIO and SAR, and on Benton's Line Orientation Judgement only in patient SAR. Patient MU was defective as far as the Street's Completion and the Benton's Face Recognition tests were concerned.

On a more formal investigation of their perceptual deficits, all patients were spared on the BORB Foreshortened View, Minimal Features and Item Match subtests; however, Patients MU, CAL, MIO and SAR were all impaired on both versions of the Object Decision subtests of the BORB. On the VOSP battery, patients BAI and BAR were shown to be completely unaffected, with the only exception of a defective performance on Cube Analysis subtest in patient BAI. Patient CAL was generally good on the VOSP subtests, except for Silhouettes and Object Decision subtests, patient MIO presented an impairment on Silhouettes and Progressive Silhouettes, while the only deficit showed by SAR was limited to the Position Discrimination subtest. Patient MU was instead impaired on the Incomplete letters, Silhouettes, Object Decision and Progressive Silhouettes subtests, while his ability to perform a spatial analysis was preserved in all subtests of the VOSP.

Only patient BAI could name and identify colours without problems, whereas CAL and SAR colour naming abilities were damaged. In contrast, patients MU, BAR and MIO were unable both to correctly identify and name colours on a test for colour perception.

Therefore, although patients presented a patchy pattern of preserved/impaired general neuropsychological skills, all of them clearly showed to have suffered from a neurological damage, which disrupted to different extent various aspects of their cognitive functions.

In the following chapters patients' performance on a large array of experimental tasks, aimed at exploring the status of their semantic memory system, was tightly examined, focusing on semantic knowledge of three main conceptual domains, such as living things, man-made artefacts and a novel sensory quality category involving different kinds of “mass”.

Chapter 5: Experimental investigation

5.1 General introduction

In the present work a group of neurological patients was examined in order to address several interdependent issues related to category-specificity effects. The category specific deficits most classically described are held to involve the selective impairment of patients' knowledge of a semantic category, such as living things, or, although less frequently reported, man-made artefacts. Herpes encephalitis patients were often reported to show a category specific deficit selectively affecting the living things class, in contrast to an advantage for their knowledge associated to man-made artefacts.

The performance of a group of patients was assessed through an extensive array of tasks. All patients suffered from an episode of probable herpes simplex virus encephalitis, and, as it will be widely described in the following methodological section, were comparable as a group in terms of their performance with respect to the man-made artefacts class. The performance of a key patient, MU, who showed the classical category specific deficit affecting the living things class, was usually compared to that of the other patients, who were used as a novel form of control group, matched to him in terms of the aetiology and of their mean performance with man-made artefacts. However, in some of the tasks MU's performance had to be compared to that of normal subjects, matched to the patient on the basis of comparable age, sex and schooling.

Patients' semantic memory performance was assessed through four experimental sections, which were aimed at addressing different questions. The conceptual knowledge of two classically investigated semantic domains, living things and man-made artefacts, was probed along with that of a new semantic category, comprising different kinds of "mass" stimuli, such as edible substances, liquids and materials.

The semantic category of "mass" involves concepts such as substances, liquids and materials that should be discriminated much more through an analysis based in terms of texture, colour and other surface properties which can be considered on the whole as "sensory qualities", as proposed by Warrington and Shallice (1984). Their form, although being a visual property, cannot provide critical hints for the identification of an exemplar of the "mass" category with respect to another, since substances, liquids and materials have no characteristic shape. In addition, the absence of a distinctive shape, conceived in terms of De Renzi and Lucchelli's (1994) and Tyler and Moss's (1997) theoretical account, does not suggest any relation to a specific function. Although "mass" stimuli have usually lots of functions, they are not characterised by a precise function, such as in the case of man-made artefacts, which are instead associated to well defined functions. Therefore, the lack of clear form-function relations should not contribute to the process of discrimination of "mass" stimuli, which should instead be based on the analysis of sensory quality properties. Moreover, exemplars of the living things domain, are more easily identified by colour and texture (Warrington and Shallice, 1984), while their visual shape cannot always lead to the discrimination between members of the same category. Again in this case the form of a living kind does not imply a direct link to its function, as proposed by De Renzi and Lucchelli (1994). In addition, the large majority of living things is not strictly related to specific functions. Man-made artefacts, however, can be thought to be characterised by functions that are closely connected to the form they have (De Renzi and Lucchelli, 1994; Tyler and Moss, 1997), and they usually have very distinctive functions. The role played by form-function relation might allow their identification in terms of functional properties, whereas their sensory quality attributes should be less relevant in the identification process.

Therefore, the strong link to texture and colour qualities, the lack of a distinctive shape and of a definite function, and the absence of strong form-function relations, would suggest an intimate similarity between the process of identification of both the "mass" category and the living things class. In contrast, man-made artefacts should behave in a different fashion with respect to living things and "mass" stimuli, because their discrimination is much more conceivable in terms of their function, or, better, their form-function relations, while the contribution of sensory quality properties should be minimal.

Therefore, the principal aim of the present work was that of examining the plausibility of an intimate relation connecting the living things class to the novel "sensory quality" category of "mass", through the adoption of a large series of tasks, subdivided in four experimental sections.

Firstly, the general categorical knowledge of the three main domains of living things, man-made artefacts and "mass" stimuli was examined in the first two experimental sections. A preliminary investigation of patients' performance when presented with the three main classes of stimuli was carried out in the first section (5.3), where a series of classically used tasks was adopted: visual confrontation and after verbal definition naming tasks, word-to-picture and picture-to-word matching tasks, questionnaires about functional and sensory knowledge of the stimuli. The main aim of this experimental section was therefore that of achieving a pilot picture of patients' semantic knowledge, and a useful guideline to following testing sessions. In the second experimental section (5.4), a larger set of tasks was employed to further examine patients' broad knowledge of these categories, and in particular that of the "mass" class, since this semantic category was never investigated in a systematic way. Both sections were characterised by the effort to compare, firstly, MU's performance with living things to that related to man-made artefacts, where a <u>discrepant</u> behaviour was expected as regards to the two semantic classes, as in the classical studies within the category specificity field. Secondly, his performance with respect to living things and "mass" was examined, and a <u>similar</u> behaviour with both categories across tasks was expected, on the hypothesis that both domains can be considered as "sensory quality" categories.

Furthermore, the knowledge of different types of semantic attributes was probed in the third experimental investigation (5.5) from two divergent perspectives: the spontaneous production of conceptual properties (sections 5.5.2 and 5.5.4) on the one hand, and the ability to verify semantic features related to living things, man-made artefacts and "mass" categories (sections 5.5.6 and 5.5.8) on the other.

Feature knowledge has been already probed in previous studies, leading both to discrepant findings and conclusions. For example, De Renzi and Lucchelli (1994) showed that their HSE patient, with a selective impairment for living things, tended to exhibit poor knowledge of perceptual attributes, for every type of category, while her performance with functional/associative attributes was intact. However, an interaction between category and attribute knowledge was described in HSE patients, leading to an impaired performance on tasks assessing perceptual knowledge about living things (Sartori and Job, 1988; Silveri and Gainotti, 1988; Gainotti and Silveri, 1996). Moreover, other authors (Laiacona et al., 1993a) described two HSE patients who, although being impaired in naming and comprehension of living things, were equally poor in a questionnaire tapping perceptual and functional/associative knowledge of living things and man-made artefacts. Lambon-Ralph et al. (1998) described two patients who presented quite different patterns of performance: the first one, a DAT patient, showed an impairment for the living things class, but demonstrated no difference as regards to her visual and functional/associative knowledge. The second patient, affected by semantic dementia, did not show a category specific deficit for living things, but was selectively impaired in her knowledge of visual properties.

However, in the present study a very large item set was used in both types of task, which are strictly linked in that both uses the same set of target stimuli, though for different purposes. Therefore, the same stimulus sets adopted to test patients' spontaneous production of features (sections 5.5.2 and 5.5.4) were then used when item-feature pairs were provided to patients in the attribute verification task (sections 5.5.6 and 5.5.8). Although the tasks sharply differ in their task demands, an attempt to compare the broad results from both tests was performed, with particular reference to the relation between living things/man-made artefacts, on the one hand, and living things/"mass" on the other. Special attention was devoted to the patients' ability to produce and verify four different types of semantic features: the semantic category, encyclopaedic information, functional and sensory attributes.

Finally, on the light of considerations developed from the examination of the whole array of findings drawn in the three previous experimental sections, a re-analysis of two fundamental semantic properties, namely functional and sensory features, was performed, under the main idea of redefining the meaning of these notions, which were often confused in previous studies. Therefore, a systematic analysis of "sensory" notion was carried out in section 5.6.2: general vs. specific sensory features were separated and contrasted (section 5.6.2.1); moreover, the functional- (section 5.6.2.2) and action-related (section 5.6.2.3) aspects implicated in the notion of sensory properties were examined. On a comparable ground, the notion of "objects' function" was re-analysed (section 5.6.4): again, functional- (section 5.6.4.3) and action-related (section 5.6.4.4) aspects, often mixed in the general notion of function, were segregated, in order to verify whether an independence or interdependence characterises this widely used concept. However, the last experimental section (5.6) is only preliminary in nature, and the findings obtained from the single patient MU should be considered provisional. Nevertheless, the results which can be drawn from this last section may provide useful suggestions for future studies.

5.2 New methodology

Many factors have been held to be involved in the difference in performance of category specific patients across semantic domains. The standard way of dealing with the problem is to select stimuli so that they are controlled across the factors. This procedure was usually adopted, but the method is subject to the problem that new factors may always be suggested to be relevant. Furthermore, the ceiling effect in normal subjects has lead to the adoption of the procedure of using small sets of stimuli matched on many characteristics. Such a stimulus set is however potentially highly idiosyncratic, since the subsets are unrepresentative within their categories. Moreover, if any other factor is later held to be relevant, there is no reason why the adopted stimuli will be matched on this factor.

A second method was therefore adopted as well. An initial group of five neurological patients (MU, BAI, BAR, MIO and SAR) was thoroughly examined along a large series of tasks (section 5.3). The aim of this investigation was to establish the degree and quality of conceptual disruption in this group of patients. The examination of each patient on the same range of tasks allowed patients' performance to be more tightly confronted.

From a general overview of patients' performance across experimental investigations, only in one of the patients, MU, was there found a very marked category specific effect across categories, while the others showed less or no difference in the degree of impairment. On many aspects of their performance the remaining patients were on average roughly comparable to MU. Most critically the initial group of HSE patients was matched for degree of impairment with the critical patient MU, on performance on man-made artefacts. In addition, HSE patients were likely to have other similar characteristics because their lesions arose from the same probable aetiology. Thus, if another factor is held to be relevant it is likely to be affecting the patient controls as well. In this research (section 5.3), MU's performance was therefore contrasted to that of the group of the other five HSE patients, who were treated as a control group. This procedure, adopted any time it was viable, allows a stronger means of disentangling the effects of potentially confounding variables acting on possibly unbalanced dimensions of the stimuli.

The patients were selected on two criteria: (i) they had had an episode of probable herpes simplex encephalitis; (ii) they were impaired with respect to normal controls on several tasks administered during the general neuropsychological assessment (see section 4.4, and tables 5 and 6). Even though the diagnosis of herpes encephalitis is not unconditionally straightforward for all the patients (section 4.2.1), the observation of neuropsychological deficits in this group of patients gives support to the conclusion that they suffered from a neurological damage which made them not completely cognitively spared (section 4.3.1). Although patient CAL did not participated to the first experimental investigation, his neuropsychological profile is not completely unimpaired (section 4.3.1.4): therefore the same line of reasoning can hold also in his case. Moreover, as will be seen in the experimental section 5.4.2.1, patient CAL showed a level of performance comparable to that of the other patients, and MU in particular, as far as man-made artefacts were concerned.

In addition, as reported below in the first experimental sections, each of the five initial patients showed an highly impaired performance in five experimental naming tasks in comparison to 25 normal subjects (see section 5.3.1.1). The above observations supply further support to the decision of using the probable herpes encephalitis patients as a control group for a patient, MU, considered critical for the present study.

Moreover, Gonnerman et al. (1997) have argued that a different degree of impairment in AD patients could give rise to different patterns of performance on tasks involving living things and man-made artefacts categories. They hold the animate-inanimate dissociation may potentially arise at the more severe levels of impairment present in the patients at a later stage of their illness. The use of patient controls affected by the same neurological disease as MU, and presenting a broad range of performance on different tasks, should allow the importance of the degree of impairment to be assessed.

Unfortunately, the long time required to carry out the entire experimental investigation did not allow the participation of the entire group of six HSE patients to all the tasks. As pointed out before, five patients (MU, BAI, BAR, MIO and SAR) entered the first experimental investigation (section 5.3), which motivated and inspired each of the subsequent experimental sections. However, a primary point has to be made with respect to the series of tasks involving the classical semantic domains of living things and man-made artefacts: the basic group of neurological patients was involved both in the second (5.4.2) and third experimental section (5.5.2 and

5.5.6), with the exception of BAR, who could not participate in all experimental sections but the first one (section 5.3), and patient CAL, who entered instead the second (section 5.4.2) and third experimental investigation (sections 5.5.2 and 5.5.6). A second consideration has to be made when tasks involving the assessment of the knowledge of the "mass" category are taken into account. At variance to the first wide investigation (section 5.3), carried out on patients MU, BAI, BAR, MIO and SAR, in the second (5.4.4) and third (5.5.4 and 5.5.8) experimental sections only MU's performance was examined, in comparison to groups of normal subjects. The use of normal subjects as controls with respect to a single patient's performance is liable to a basic criticism. Normal healthy controls, although matched to a patient by age, education and other critical factors, will usually show an almost perfect level of performance on most of the tasks on which the patient is examined. Nonetheless, this procedure was necessarily adopted in this work as regards to a wide set of experimental tasks (see second experimental section: 5.4.4; third experimental section: 5.5.4 and 5.5.8), whenever the group of patient controls was unavailable for testing.

A further comment has to be done as regard to the statistical procedures adopted, where was possible and relevant, with respect to the findings. To analyse the results statistically requires certain approximating assumptions, which may not entirely hold. Dissociations observed in MU were therefore assessed by two segregate procedures. First rough normality in the distribution of scores in the control patients was assumed, and how deviant MU was from their distribution was tested by using Z scores. Secondly whether there was an effect of the critical variable was tested separately in MU and in the control patient group. MU's dissociation was analysed through the use of the χ^2, while an item by item analysis, related to the semantic categories involved, was carried out on the performance of the patient controls by a Mann Whithey test. In some specific instances, an analysis of the discrepant performance with different semantic features was required and an item by item analysis, related to the different feature types, was performed both on MU's and patient controls' performance with the Wilcoxon test. Effects to be interpreted theoretically will be those for which there is a highly significant value of Z and for which MU shows a significant effect of the variable but the control group does not.

A final point has to be made as regards to the last experimental section (5.6): this has to be considered a very preliminary investigation, aimed at segregating different types and levels of semantic attribute knowledge which might play some influence when conceptual competence is assessed in patients showing category specific deficits. Only patient MU underwent this series of merely explorative tasks. The provisional nature of the findings drawn from the fourth experimental investigation is unequivocally stated throughout the whole section, and the results, although valuable criticisms and suggestions as regards to both previous studies of category specificity and preceding empirical parts of the present work, will be just considered as a starting point for future and much more controlled experimental settings.

5.3 A novel category specific effect

5.3.1 Introduction

The first experimental investigation can be conceived as an initial attempt at exploring the patients' semantic competencies with respect to the classical domains involved in category specific effects, such as living things and man-made artefacts, and three new classes of stimuli, thought to be sensitive to "sensory-quality" damage, namely, edible substances, liquids and materials.

As outlined in section 5.1, different types of "mass" stimuli should be visually discriminated mainly through an analysis of their colour, texture, and other general visual properties, which are usually considered sensory attributes also deeply involved in the representation of living things. This consideration led to the inclusion of these novel categories as critical to the verification of Warrington and Shallice's (1984) hypothesis. In their study, the authors reported a deficit damaging both the categories of living things and foods. However, in several subsequent works on category specificity, a deficit for foods and also other categories, such as textiles and precious stones, was described, but so far there have been no experimental studies addressing purposely the co-existence of a deficit for living things along with an impairment for different classes belonging to the "mass" semantic category. If both living things and "mass" categories are processed mainly in terms of their sensory quality properties, a similar behaviour should be observed in patients' performance with respect to these semantic classes. In contrast, man-made artefacts should lead to a pattern of performance sharply different with respect to "mass" stimuli and living things, insofar as their processing should be based mostly on the analysis of functional properties (Warrington and Shallice, 1984), or, better, form-function relations (De Renzi and Lucchelli, 1994; Tyler and Moss, 1997).

In this first experimental section the performance of the initial group of five HSE patients (MU, BAR, BAI, MIO and SAR) will be examined through a series of tasks aimed at probing semantic knowledge for the five categories as respect to both the verbal and visual modalities (the stimulus sets used in this experimental section are listed in appendix B). Patients' semantic knowledge of living things and man-made artefacts categories was probed through the use of a series of tasks, involving visual confrontation naming, functional and sensory verbal descriptions naming, word-to-picture and picture-to-word matching, and finally a questionnaire assessing functional and sensory knowledge. However, the three classes of "mass" stimuli were only assessed through the visual confrontation naming task and the questionnaire.

5.3.1.1 Confrontation naming of five categories

In order to investigate the presence of category specific deficits in the group of herpes patients, a series of five different sets of stimuli was prepared for naming to visual confrontation and administered to patients. Two sets of black and white line drawings representing *living things* and *man-made artefacts* were taken from Snodgrass and Vanderwart's (1980) stimuli, and presented on white cards of 10×15 cm. Living things (39 items) and man-made artefacts (36 items), were matched by word frequency of usage in the Italian language (Dizionario di Frequenza della Lingua Italiana, CNR, unpublished), and on item familiarity, visual complexity and name agreement, the values of the last three dimensions of the stimuli being taken from the Snodgrass and Vanderwart's (1980) norms.

Patients were also presented with a set of actual *liquids*, most of them edible and some of them non-edible (12 items, e.g. olive oil, alcohol) and a set of actual solid *edible substances* (13 items, e.g. ground pepper, Nutella cream); in both cases the stimuli were presented to subjects inside transparent boxes and were not allowed to smell at them. Finally, actual non-edible *materials* of comparable dimensions (10×14cm) (23 items, e.g. wood, glass) were presented to patients, who were not allowed to touch the materials.

In order to determine to what extent the whole set of stimuli was well known by normal subjects, 25 healthy normal controls, divided in groups of five and of sex, age and education comparable to that of each patient, were asked to name the two sets of living things (39) and man-made artefacts (36), and a larger set of liquids (18), edible substances (20) and materials (32): for the experimental tasks only those stimuli were selected that were correctly named by normal subjects at least at a rate of 95%.

The five sets of items were administered to patients in separate test sessions in random order, and within each set the stimuli were presented one at a time randomly, with unlimited time for response. As described above, the same five sets of items were administered to the normal subjects group: their performance on the five naming tasks is reported in figures 4 and 5, so that a direct comparison can be made between their scores relative to those obtained by the five patients.

From an analysis of each patient's overall performance on the five naming tasks, a clear deficit arose when compared to the mean performance of the normal controls group (patient MU: $z=-15.9$, $p<0.0001$; patient BAI: $z=-2.2$, $p<0.01$; patient BAR: $z=-9.9$, $p<0.0001$; patient MIO: $z=-11$, $p<0.0001$; patient SAR: $z=-3.2$, $p<0.001$).

First, the pattern of performance of the whole group across the tasks was considered. Figure 4 shows how the five patients perform in the five naming tasks. A log linear analysis, based on a 5×5×2 contingency table, gives a significant interaction between conditions and patients (Patients×Tasks×Correct-Wrong answers: $\chi^2=42.4$, $df=16$, $p<0.0005$). However, if consideration is restricted to living things and the three sets, substances, liquids and materials (Figure 5) then the interaction is not significant (Patients×Tasks×Correct-Wrong answers: $\chi^2=19.6$, $df=12$, $p>0.05$). The near significant trend is entirely accounted for by a potential difference over substances. Indeed if one compares living things, liquids and materials, then the log linear interaction shows absolutely no effect (Patients×Tasks×Correct-Wrong answers: $\chi^2=2.7$, $df=8$, $p>0.5$). This is reflected in the more detailed pattern of correlations between tasks (Pearson correlation coefficient, one tail): living things correlate highly with liquids (0.97, $p<0.01$) and materials (0.99, $p<0.001$), and liquids also correlate highly with materials (0.96, $p<0.01$). Performance on man-made artefacts and on substances do not correlate significantly with any of the other conditions. Of particular interest is the correlation between performance on living things and on materials because materials are not edible, and the effect is therefore different from the well known food/living things correlation. We therefore have a virtually identical pattern of performance over the five patients across three categories —living things, liquids and materials— a fourth, edible substances, showing a non-significant trend to be different. Crucially, man-made artefacts behave very differently from the critical three.

Why should man-made artefacts behave so differently? One patient (MU) showed the type of strong dissociation characteristic of the originally described category-specific herpes patients (75% correct with man-made artefacts vs. 33% correct with living things). The other patients scored rather differently the one from the other: MIO showed an impairment with both the categories (47% and 56% correct with man-made artefacts and living things respectively). Two patients obtained comparable results with the two classes of stimuli (BAI 90% and SAR 92% correct with man-made artefacts, BAI 97% and SAR 90% correct with living). BAR was the only patient who showed a mild category specific deficit (78% and 56% correct with artefacts and living things respectively). If these four patients are treated as a group then they are matched for disease process and for overall level of performance on the key artefact category. They therefore form an appropriate control group for the one patient who shows a marked category specific effect of the type previously described with herpes simplex encephalitis. It should be noted that the inclusion in the patient controls of BAR, who has minor effect in the same direction as MU, is a conservative procedure, since his inclusion will tend to reduce any differences between MU and the patient controls.

Considering therefore MU from a single case perspective, it can be seen that his performance in naming *living things*, *edible substances*, *liquids* and *materials* differs significantly from that of the mean performance of the patient controls, as shown in table 7, which gives z scores and level of significance for a normal distribution, one tail (for living things MU: 33%, patient controls: 75%; z=-1.9, p<0.05; edible substances MU: 0%, patient controls: 67%; z=-9.1, p <0.0001; liquids MU: 17%, patient controls: 63%; z=-1.57, p=0.058; materials MU: 22%, patient controls: 67%; z=-1.61, p=0.054). In sharp contrast, MU does not differ at all from the other patients in naming man-made artefacts (MU: 75%, patient controls: 76%; z=-0.1, p>0.1). Clearly selecting MU for special attention, while no different from the standard practice of single-case methodology, can be viewed statistically as post-hoc selection. It is important therefore that analogous dissociations relating to the same categories occur in subsequent experiments to be reported later in this and also subsequent experimental sections.

Table 7: The performance of MU and patient controls on semantic tasks

	MAN-MADE ARTEFACTS			LIVING			SUBSTANCES			LIQUIDS			MATERIALS		
	MU%	Contr%. *(sd)*	z (p)	MU%	Contr% *(sd)*	z (p)	MU%	Contr% *(sd)*	z (p)	MU%	Contr% *(sd)*	z (p)	MU%	Contr% *(sd)*	z (p)
Naming															
Visual Confrontation	**75**	76 *(20.4)*	-0.1 (>0.1)	**33***	75 *(21.7)*	-1.9 (<0.05)	**0*****	67 *(7.4)*	-9.1 (<0.0001)	**17***	63 *(29.3)*	-1.57 (=0.058)	**22***	67 *(28)*	-1.61 (=0.054)
Functional Description	**80**	69 *(20.2)*	+0.6 (>0.1)	**35***	73 *(24)*	-1.58 (=0.057)									
Sensory Description	**65**	54 *(29.3)*	+0.4 (>0.1)	**20**	49 *(22.5)*	-1.3 (>0.05)									
Matching															
Word-to-Picture	**100**	94 *(7.9)*	+0.7 (>0.1)	**61***	87 *(14.6)*	-1.8 (<0.05)									
Picture-to-Word	**83**	83 *(17.6)*	0.00 (=0.5)	**72*****	94 *(0)*	-10 (<0.0001)									
Questionnaires															
Functional attributes	**83**	87 *(10.2)*	-0.4 (>0.1)	**73****	88 *(7.3)*	-2.1 (<0.05)	**80***	93 *(8)*	-1.7 (<0.05)	**100**	85 *(34.7)*	+0.4 (>0.1)	**64****	86 *(10.9)*	-2.1 (<0.05)
Sensory attributes	**93**	91 *(8.2)*	+0.1 (>0.1)	**74***	88 *(9)*	-1.55 (=0.06)	**50***	71 *(11.8)*	-1.8 (<0.05)	**67**	81 *(9.7)*	-1.44 (=0.075)	**56***	76 *(10.7)*	-1.8 (<0.05)

*Mean, standard deviation (sd), z score (z), and significance level, one tail, (**p**), for comparison of MU with patient controls.*

It must be stressed here that the dissociation between living and man-made artefacts shown by MU cannot be easily attributed to an artefact affecting the item set, since, as above mentioned, *living* and *man-made artefacts* items were matched for all the variables that are usually expected to influence category specific effects, namely, word frequency, picture familiarity, visual complexity and name agreement (see table 8). More critically, the patient controls show no such effect, even though they are matched for performance on man made artefacts. Thus a Funnell or Gonnerman type of explanation, as outlined above, is clearly implausible for the group as a whole.

Table 8: Mean and standard deviation values for the living and man-made artefact stimuli

	Word Frequency	Picture Familiarity	Visual Complexity	Name Agreement
Living				
Mean	2.4	3.1	3.1	0.4
sd	*1.4*	*0.7*	*0.9*	*0.4*
Artefacts				
Mean	2.5	3.2	3	0.4
sd	*1.3*	*0.8*	*0.7*	*0.4*

Word frequency means were calculated from the values presented in the Dizionario di Frequenza della Lingua Italiana, CNR (unpublished). Picture familiarity and visual complexity are calculated from the mean values given by subjects to pictures on a 5 point scale. Name agreement score is calculated through the information statistic H on the basis of the number of different names given to each picture and the proportion of subjects giving each name. The H value ranges from 0 (perfect name agreement) to 1 (same frequency of, say, two different names relative to the same picture (taken from Snodgrass and Vanderwart, 1980).

In view of the effect of frequency in some herpes simplex patients, stimuli from the living and the man-made artefact sets were divided into high frequency and low frequency subsets, with the remaining variables remaining closely matched within the subsets (see table 9). MU named correctly 13/17 (76%) high frequency and 14/19 (74%) low frequency man-made artefacts, showing no significant difference between the two subsets, while the patient controls named correctly 81% of high frequency and 72% of low frequency man-made artefacts, with no difference between the two subsets (χ^2=0.39, df=1, p>0.5). On the other hand, with living items MU was correct on 10/17 (59%) high frequency and 3/22 (14%) low frequency items, with a significant facilitation for high frequency living things (χ^2=8.8; df=1; p=<0.005); patient controls did not show a reliable difference in naming high frequency and low frequency living things (81% and 70% correct respectively; χ^2=0.5, df=1, p>0.5).

Table 9: Mean and standard deviation for the living and man-made artefact stimuli when divided into high and low frequency subsets

		Word Frequency	Picture familiarity	Visual Complexity	Name agreement
Living					
LF	Mean	1.4	3.1	3	0.4
	sd	*0.9*	*0.5*	*0.9*	*0.3*
HF	Mean	3.6	3.1	3.4	0.4
	sd	*0.7*	*0.9*	*0.8*	*0.5*
Artefacts					
LF	Mean	1.5	3.1	3.1	0.4
	sd	*0.9*	*1*	*0.8*	*0.4*
HF	Mean	3.5	3.3	2.9	0.5
	sd	*0.6*	*0.6*	*0.8*	*0.5*

For the means used see legend to table 8.

Might visual complexity also be a factor affecting MU's performance on naming tasks with living and non-living things? An analysis of variance in which familiarity and visual complexity were used as covariates, showed Item Familiarity to be a factor which affects MU's performance significantly ($F=5.3$, $df=1$, $p<0.05$), a similar result to the one described above with word frequency. Visual Complexity was not however a significant factor as a source of variation on MU's performance ($F=1.9$, $df=1$, $p>0.5$).

In order to take into account MU's problems with the Silhouettes and Progressive Silhouettes subtests of the VOSP, in which the stimuli were perhaps too complex to be correctly recognised, being both blackened and distorted, a further visual confrontation naming task was administered to him. Stimuli were blackened versions of pictures taken from the Snodgrass and Vanderwart's set, being therefore similar to the VOSP's black items. However, they were neither rotated nor distorted, unlike the Silhouettes and Progressive Silhouettes tests. In addition, items were divided into living things and man-made artefacts, and were closely matched across categories by word frequency, picture familiarity, visual complexity and name agreement. MU showed the usual strong dissociation between living things (9/50 correct) and man-made artefacts (22/50 correct) ($\chi^2=7.9$, $df=1$, $p<0.005$), but also a general decline in his performance in naming black silhouettes of artefacts (only 44% correct) was observed when compared to the standard naming tests. These findings therefore suggest that manipulations of the stimuli other than the blackening of pictures, such as rotation and distortion, might have influenced MU's performance on these VOSP subtests. Moreover when the items presented as Snodgrass and Vanderwart (1980) pictures were given to MU as very clear coloured drawings (taken from a children's book) he named 31/36 (86.1% correct) with artefacts and 12/39 (30.8% correct) with living things very similar to the Snodgrass and Vanderwart picture results. This addition of colour provided no amelioration of the living things deficit. MU's performance was further examined in order to verify his consistency in answering to the two naming tasks employing either black and white line drawings or coloured drawings: a significant consistency was observed in MU's performance with respect to the two sets of items (contingency coefficient $C= 0.426$, $p<0.005$).

5.3.1.2 Naming from functional and perceptual descriptions of living things and man-made artefacts

In order to explore whether MU's naming deficit with living things was limited to the presentation of stimuli in the visual modality or was also shared by input in the auditory verbal modality, a series of 40 descriptions were presented orally to patients in two separate sessions. Items were again divided into the two main categories of living and man-made artefacts. Verbal descriptions were also devised in order to stress either the structural details of the stimuli or the functional-encyclopaedic attributes. In the first session, 20 functional (10 living items and 10 man-made artefacts items), and 20 perceptual descriptions (10 different living items and 10 different man-made artefacts items), were read to patients, while in the second session the same items were used as in the previous one, but the functional and perceptual descriptions were provided for the complementary set of items.

In naming living and man-made artefacts from oral description the control patients demonstrated no major differences between living and man-made artefacts for either functional or perceptual descriptions. Indeed the percentages of correct responses to both functional and perceptual descriptions are very similar for living and man-made artefacts items, except in patient MU (see table 10). The patient controls, in contrast, did not show any significant difference between living things and man-made artefacts in the case of both functional ($\chi^2=0.27$, df=1, $p>0.5$) and structural ($\chi^2=0.4$, df=1, $p>0.5$) verbal descriptions. MU's responses to living things are much poorer than those to man-made artefacts, both with functional ($\chi^2=8.3$, df=1, $p<0.005$) and perceptual ($\chi^2=8.3$, df=1, p<0.005) descriptions.

For living things MU is significantly worse than the patient controls for functional descriptions, as shown in table 7. A similar trend in the same direction in naming from structural verbal description was observed but did not reach significance. For man-made artefacts MU is comparable to the patient controls for both types of descriptions, being slightly above the control group. The living thing deficit is again present and there is no suggestion of it being limited to structural descriptions.

Table 10: Percentage correct scores for naming living and man-made artefact stimuli from verbal description, in which either functional or sensory attributes were emphasised

	Functional artefacts	**Sensory artefacts**	**Artefacts**	**Functional living**	**Sensory living**	**Living**
MU	80	65	73	35	20	28
Patient controls	**69**	**54**	**61**	73	49	61
sd	*20.2*	*29.3*	*24.4*	*24*	*22.5*	*22.7*
z	0.56	0.4	0.5	-1.58	-1.3	-1.5
p	**>0.1**	**>0.1**	**>0.1**	**=0.057**	**>0.5**	**=0.067**

5.3.1.3 Knowledge of five categories

Laiacona et al. (1993b) developed the Italian version of a test, similar to that originally devised by Chertkow et al. (1992), that assesses the knowledge patients have about attributes pertaining to a concept. Patients are asked to answer 6 questions for each item, which is presented in the auditory-verbal modality, by choosing the right response from three alternatives. Items belong to 8 different classes of 10 items each (utensils, vehicles, furniture, musical instruments, animals, fruits, vegetables and body parts). The knowledge patients have of superordinate, perceptual and functional information about a concept was assessed, and the number of correct responses for each type of item and for each type of information recorded.

In this task all patients but BAI were shown to be severely impaired (patient MU: z=-7.59, p<0.0001; patient BAR: z=-3.62, p<0.0001; patient MIO: z=-11.19, p<0.0001; patient SAR: z=-1.88, p<0.05; patient BAI:

z=-1.01, ns) with respect to the normative data obtained from a group of normal Italian subjects by Laiacona et al. (1993b).

Comparing MU's performance with respect to the patient controls, as shown in tables 11 and 12, he performed significantly worse with living stimuli and foods combined (animals, fruits, vegetables). However he has no problem with man-made artefacts, being almost identical to the controls. Interestingly he is only slightly worse than patient controls with musical instruments and identical with body parts. The impairment occurred in the perceptual-subordinate on confrontation and in the functional-contextual subordinate conditions.

Table 11: Percentage correct responses of MU and control patients for each of eight classes of stimuli on a 2 or 3 alternative forced choice test

	Utensils	*Vehicles*	*Furniture*	Artefacts	*Animals*	*Fruits*	*Vegetables*	Living	*Musical instruments*	*Body parts*
MU	93	97	98	*92*	68	80	68	*72*	78	97
Patient controls	**92**	**95**	**94**	*92*	**85**	**88**	**88**	*87*	**84**	**96**
sd	*8.8*	*7.6*	*6.5*	*8.01*	*14.6*	*9.1*	*4.95*	*9*	*10.3*	*2.9*
z	0.15	0.3	0.65	*0.06*	-1.14	-0.88	-3.95	*-1.63*	-0.56	0.3
p	**>0.5**	**>0.1**	**>0.1**	*>0.1*	**>0.1**	**>0.1**	**<0.0001**	*=0.052*	**>0.1**	**>0.1**

Laiacona et al.'s (1993b) test

Table 12: Percentage correct responses of MU and patient controls for each of six types of knowledge

	General Superordinate	**Intracategorical Superordinate**	**Perceptual subordinate**	**Perceptual subordinate on confrontation**	**Functional subordinate**	**Functional-contextual subordinate**
MU	100	89	83	84	79	76
Patient controls	**95**	**93**	**85**	**94**	**85**	**90**
sd	*7.4*	*8.4*	*9.2*	*5.4*	*8.2*	*8.6*
z	0.7	-0.44	-0.3	-1.9	-0.72	-1.63
p	**>0.1**	**>0.1**	**>0.1**	**<0.05**	**>0.1**	**=0.052**

Laiacona et al.'s (1993b) test

To assess the knowledge patients have of attributes pertaining to the different categories examined earlier, a procedure based on that of Laiacona et al. (1993b) was used. The patients were asked to answer 6 questions related to each item; items belong to 3 different class: *edible substances* (15 items), *liquids* (12 items) and *materials* (26 items). The type of information required was comparable to that used with the Laiacona et al.'s

(1993b) test (superordinate, perceptual and functional information). A questionnaire on knowledge of properties of different types of edible substances, liquids and materials was made up in order to determine the extent to which information regarding different exemplars of the novel "sensory-quality" categories is available to patients. MU's performance on the questionnaire on properties of the novel "sensory-quality" class is much worse than that of the other patients. By comparing MU's results with that of the patient controls (see table 7), he shows a defective knowledge of both functional ($z=-2.04$, $p<0.05$) and perceptual ($z=-2.5$, $p<0.01$) information. When knowledge of superordinate information, perceptual, and functional attributes was examined across the different types of stimuli, MU had a performance level similar to that of patient controls in retrieving information of superordinate level with respect to functional and perceptual information. However (see figures 6 and 7), in contrast, as shown in table 7, he showed a difference with respect to patient controls for perceptual knowledge of both substances ($z=-1.8$, $p<0.05$) and materials ($z=-1.8$, $p<0.05$) —with a mild trend in the same direction observed for liquids ($z=-1.44$, $p=0.075$). In addition he was impaired relative to controls for functional knowledge of both substances ($z=-1.7$, $p<0.05$) and materials ($z=-2.1$, $p<0.05$). However he was not impaired at functional knowledge of liquids.

The pattern of performance shown by the whole group of HSE patients across the two questionnaires was then examined with respect to the knowledge of functional and sensory properties. As observed in the case of the five naming tasks (section 5.3.1.1), a log linear analysis, based on a 5×5×2 contingency table, was performed. A significant interaction between patients and conditions (see figure 6) was observed when all the five different sets of questions were considered (Patients×Category×Correct-Wrong answers: $\chi^2=35.2$, df=16, $p<0.005$). Perhaps not surprisingly, when only living things, substances, liquids and materials were taken into consideration a significant interaction Patients×Conditions was again found (Patients×Category×Correct-Wrong answers: $\chi^2=31.6$, df=12, $p<0.005$), and this result might be attributed to the behaviour of liquids, which were not found to be equivalent to the other sets (see table 7 and figure 6). However, when both artefacts and liquids were removed from the analysis, no significant interaction was observed (Patients×Category×Correct-Wrong answers: $\chi^2=7.4$, df=8, $p>0.1$), suggesting that at least three of the categories considered, living things, substances and materials, show the same behaviour across patients' performance on the questionnaires (see figure 7).

5.3.1.4 Matching tasks

Two matching to sample tasks were devised and administered to patients, a word-to-picture (36 items) and a picture-to-word (36 items) matching tasks. Each of the two tasks employed 18 living and 18 man-made artefact items, which were the same in the two versions of the task; the two matching tasks were administered in separate sessions to the group of patients. When presented with each item, patients had to choose between 5 alternatives (a target, and 4 distractors —semantically, visually, visuo-semantically, and unrelated to the target). The alternatives were pictures in the word-to-picture matching task, and written words in the picture-to-word matching task.

MU's performance (see table 7) was significantly worse than the mean performance of patient controls with living stimuli in both word-to-picture ($z=-1.8$, $p<0.05$) and picture-to-word ($z=-10$, $p<0.0001$) matching tasks; in contrast, he did not differ significantly from the mean of patient controls with man-made artefacts in both the word-to-picture ($z=+0.7$, $p>0.1$) and the picture-to-word ($z=0$, $p=0.5$) versions of the task.

5.3.2 Summary

A well defined pattern of deficits arose from the evaluation of patients' performance over a variety of tasks presented either in the visual and auditory modalities. All patients performed to a comparable level with respect to man-made artefacts, in the whole set of tasks.

However, the evaluation of their ability to deal with living things and three classes of "mass" stimuli leads to quite different conclusions. In the visual confrontation naming task (section 5.3.1.1) the level of performance shown individually by each of the patient controls is quite different when confronted to that of the other patients. Remarkably, their performance with living things is parallel to that concerning the three semantic categories of "mass" stimuli, at any different degree of impairment or preservation. However, when their performance is considered as a whole, they are much more preserved in contrast to patient MU, over all the experimental tasks.

MU, the patient who shows the most discrepant category specificity effect, with a severe damage to his knowledge of living things, is extremely defective as regards to both living things and the three novel categories of "mass" stimuli, when he is contrasted to the mean performance of patient controls (see table 13). This effect is observed both in the visual confrontation naming task (5.3.1.1) and as regards to his performance in the questionnaires (5.3.1.3) assessing functional and sensory knowledge of living things, substances and materials, with a mild tendency toward a significant effect in the case of the questionnaire about liquids. However, it is worth stressing again as, although totally equivalent to patient controls as far as artefacts are concerned, MU's deficit for living things relative to man-made artefacts is observed through the whole set of tasks as opposed to patients controls.

Table 13: MU's performance after comparison to the patient controls group in the whole set of tasks

	Artefacts	Living	Substances	Liquids	Materials
Visual confrontation naming	= $p>.1$	× $p<.05$*	× $p<.0001$*	⋇ $p=.058$	⋇ $p=.054$
Functional descriptions naming	= $p>.1$	⋇ $p=.057$			
Sensory descriptions naming	= $p>.1$	= $p>.05$			
Word-to-picture matching	= $p>.1$	× $p<.05$*			
Picture-to-word matching	= $p=.5$	× $p<.0001$*			
Questionnaire on functional attributes	= $p>.1$	× $p<.05$*	× $p<.05$*	= $p>.1$	× $p<.05$*
Questionnaire on sensory attributes	= $p>.1$	⋇ $p=.06$	× $p<.05$*	⋇ $p=.075$	× $p<.05$*

×: worse than controls; =: comparable to controls; ⋇: trend toward significance.

5.3.3 General conclusion

In the first experimental section of this work a basic series of findings was described, related to the performance in naming and semantic knowledge tasks of five patients with a diagnosis of probable herpes simplex encephalitis. As reported in previous studies of HSE patients, a selective advantage for man-made artefacts relative to living things was found. A primary aim was to examine the performance of patients showing a category-specific deficit for living things, in the present work MU, with respect to a series of new categories of "mass" stimuli. This was motivated by the fact that the semantic processing of stimuli belonging to the broad "mass" class should depend on an analysis of their sensory properties in order to be differentiated from other members of the same category. However, it has to be stressed that sensory quality information has to be conceived in terms of surface properties such as colour and texture, while the shape of "mass" items has no relevance. In fact, "mass" stimuli do not have a well defined shape which could allow discrimination among exemplars of this category. Furthermore, their functional attributes should have a minimal role in their semantic definition, since "mass" stimuli are commonly used for very different purposes, and thus this type of information should be of no much help in their discrimination from other exemplars.

The most relevant finding of this first part of the present work lays on the strikingly parallel pattern of performance found when living things and "mass" categories were examined together. This result was observed when the five visual confrontation naming tasks were taken into account (section 5.3.1.1).

An impairment affecting the knowledge associated to both living things, substances, materials and, with some exceptions, liquids, was also found in two questionnaires (see figures 6 and 7) assessing patients' verbal knowledge (section 5.3.1.3).

These results provide, from a perspective which has been never directly addressed so far, substantial support to Warrington and Shallice's (1984) theoretical account of a difference between two classical categories, living things and man-made artefacts, which has to be conceived in terms of differential processing: relevance is assumed by functional information when man-made artefacts are semantically elaborated, whereas sensory attributes are held to play a key role in the processing of sensory quality categories, such as living things and, as the present findings highlight, "mass" stimuli.

In addition, MU's deficit as regards to living things and three classes of "mass" items, cannot be easily ascribed to an impairment of visual processing, since difficulties were observed also when he was involved in tasks using verbal presentation (section 5.3.1.2).

However, looking at the pattern of deficits and preservations in patient MU over the entire set of tasks, a clear impairment affected the living things class, regardless whether functional or sensory attribute knowledge was probed. Therefore, if MU's performance is considered from this perspective the prediction of a differential impairment as regards to functional and sensory properties is not satisfied. These data seem much more in keeping with Caramazza and Shelton's (1998) position. They hypothesised that in category specific deficits semantic knowledge can be damaged only as respect to domains, excluding the critical role of cross-categorical factors such as sensory or functional knowledge.

However, the findings related to the disruption of "mass" semantic knowledge in patient MU are difficult to interpret in the light of Caramazza and Shelton's theory. Even though one could accept their highly reductionist proposal of the ontogenetic development of a semantic domain devoted to the knowledge of animals and plants, and perhaps also foods, given their relevance for survival, and, by default, the emergence of a second independent domain concerned with knowledge of artefacts, why should "mass" kinds behave as living things in patient MU? On this ground, it is worth stressing that, although edible substances were used, and the liquids set comprised mostly edible drinks, in the main class of "mass" a further category was adopted, that of materials, which cannot be ascribed to the foods class, since it included only non-edible stimuli, such as wood, glass, cork, plastic etc.

Therefore, an unequivocal conclusion cannot be drawn from the present data, which do not entirely support any of the two most relevant theories currently held to explain category-specific deficits. In the further experimental sections an attempt was made in order to achieve a better understanding of the pattern of findings described above, and additional attention will be put on patients' knowledge of semantic attributes such as sensory and functional types of information.

5.4 Reassessment of the categorical knowledge of living things, man-made artefacts and "mass" stimuli

5.4.1 Introduction

The main aim of the second experimental section was to attempt a replication of the results found in the previous experimental section (5.3) in patient MU as regards to the three main semantic domains of living things, man-made artefacts and "mass" kinds. Therefore the key purpose of this second experimental investigation was twofold. Firstly the presence and extent of the category specific deficit for living things as regards to man-made artefacts shown by patient MU was again attempted to be ascertained. Secondly, the reliability of the relation found in section 5.3 between MU's semantic knowledge associated to living things and different types of "mass" kinds was further addressed.

To accomplish these purposes two more systematic batteries of tasks, one based on living things and man-made artefacts, and the second involving "mass" stimuli were devised. Therefore, a first basic battery which comprised several tasks tapping the semantic knowledge of living things and man-made artefacts, both in the visual and verbal modalities[1] was adopted (section 5.4.2). This first battery was presented to MU and the group of control patients (BAI, CAL, MIO and SAR). As outlined in section 5.2 of this chapter, patient BAR could only participate to the first experimental investigation, while, from the second one on, patient CAL entered the study being part of the control patient group: in fact, his diagnosis of probable HSE, the general neuropsychological profile and his level of performance with man-made artefacts, allowed his inclusion in the patient control group. The assessment of semantic knowledge of three main classes of "mass" kinds, such as edible substances, liquids and materials, was accomplished through the development of a second battery of tasks (section 5.4.4). This battery was devised with the specific purpose to match, as far as possible, the array of tasks employed in the battery probing the knowledge of living things and man-made artefacts. However, it has to be stressed that the entire set of tasks regarding "mass" stimuli was presented only in the visual modality, because of some difficulties in devising tasks tapping the verbal modality. Moreover, the battery involving "mass" items was only administered to patient MU and a group of five normal subjects, matched to the patient on the relevant factors.

The fact that only one of the HSE patients, MU, underwent testing on "mass" semantic knowledge, prevented a direct comparison between his and patient controls' performance on all three semantic categories, in contrast to what could be performed in the first experimental investigation (section 5.3). However, a comparison of MU's knowledge as regards to living things/man-made artefacts classes on the one hand, and living things/"mass" categories on the other, was nonetheless possible.

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[1] I wish to thank Dr. Peter Garrard for having made available the battery he developed for the assessment of category specific deficits in semantic dementia patients and for the normative data of some key tests included in the battery.

5.4.2 Basic battery assessing the semantic knowledge of living things and man-made artefacts

This battery, kindly provided by Dr. Peter Garrard and used to verify the presence of category specific deficits in semantic dementia patients, includes a variety of tasks tapping visual and verbal modalities of input. Stimuli (the entire item set adopted in the battery is presented in appendix C) are 32 living things, where 16 are land animals (e.g. rabbit, cow), 8 birds (e.g. duck, eagle) and 8 fruits/vegetables (apple, tomato), and 32 man-made artefacts, divided in 24 household/utensils (dustbin, screwdriver) and 8 vehicles (bus, aeroplane). The battery includes five different tasks, all of them employing the whole set of 64 stimuli. For the purpose of the present study, the whole set of items was counterbalanced for all the relevant factors (see table 14), such as word frequency, familiarity, visual complexity and name agreement.

Table 14: Mean and standard deviation values for the living and man-made artefact stimuli

		Frequency	**Familiarity**	**Visual complexity**	**Name agreement**
WHOLE SET	Mean	2.04	1.1	1.09	0.4
	sd	*1.38*	*0.3*	*0.33*	*0.44*
LIVING THINGS	Mean	1.98	0.97	1.16	0.33
	sd	*1.41*	*0.31*	*0.36*	*0.36*
ARTEFACTS	Mean	2.09	1.24	1.02	0.46
	sd	*1.36*	*0.23*	*0.29*	*0.5*
Animals	Mean	2.52	0.94	1.33	0.21
	sd	*1.45*	*0.32*	*0.1*	*0.25*
Birds	Mean	1.78	0.74	1.29	0.62
	sd	*1.12*	*0.2*	*0.18*	*0.46*
Fruits/veg.	Mean	1.12	1.24	0.71	0.27
	sd	*1.22*	*0.1*	*0.45*	*0.31*
Household	Mean	1.83	1.23	0.93	0.44
	sd	*1.29*	*1.23*	*0.93*	*0.44*
Vehicles	Mean	2.85	1.27	1.32	0.53
	sd	*1.34*	*0.2*	*0.17*	*0.56*

Word frequency means were calculated from the values presented in the Dizionario di Frequenza della Lingua Italiana, CNR (unpublished). Picture familiarity and visual complexity are calculated from the mean values given by subjects to pictures on a 5 point scale. Name agreement score is calculated through the information statistic H on the basis of the number of different names given to each picture and the proportion of subjects giving each name. The H value ranges from 0 (perfect name agreement) to 1 (same frequency of, say, two different names relative to the same picture (taken from Snodgrass and Vanderwart, 1980).

In the <u>visual confrontation naming task</u> HSE patients were presented with 64 black and white line drawings, taken from the Snodgrass and Vanderwart's set (1980). Stimuli were presented one at a time on an A4 sheet. The order of administration was fixed for all patients, but items belonging to the different classes and related subcategories were randomly mixed within the list.

In naming from verbal description, a definition of each item was presented orally to patients; 64 descriptions stressed the functional properties of stimuli (e.g. duck: "A water bird, which swims in ponds, waddles on land and lay eggs"; brush: "A handheld item with a handle, used for smoothing hair or sweeping up dirt") and the remaining 64 emphasised their sensory features (e.g. duck: "A small bird with coloured feathers and webbed feet, which quacks"; brush: "An object with a long handle and stiff bristles at one end"). The two sets of definitions were administered to patients in different testing sessions in random order. As far as the verbal presentation was concerned, the total number of descriptions was adapted and translated in Italian from the original English version.

In the categorisation task, each of the stimuli of the entire item set was presented visually on a separate A4 sheet to patients in random order: patients were firstly required to perform a classification based on the two main classes of living things and man-made artefacts.

A sorting task was also administered to patients, who were presented visually with the stimuli singularly placed over 10×14 cm white cards. Patients were asked to sort stimuli into the two main domains of living things and man-made artefacts.

In the word-to-picture matching task each item was presented visually on a separate A4 sheet along with other 7 distractors. In order to enhance the difficulty of the task demands, the target stimuli and relative distractors always belonged to the same subclasses, as following: domestic animals, foreign animals, birds, fruits/vegetables, large household items, small household items, tools and vehicles.

The whole series of tasks was administered to patients (MU, BAI, CAL, MIO, SAR) in different testing sessions, in order to avoid effects which could be ascribed to practice with the item set. Patients had unlimited time for response and were allowed to examine the stimuli as long as they needed.

By the use of the first statistical method, the performance of the critical patient, MU, was compared to the mean performance of the four patient controls in each of the tasks, assuming the normality of the distribution of their scores. It is worth stressing that the second statistical procedure carried out on patient controls involved an item by item analysis belonging to the two semantic categories (32 living things and 32 man-made artefacts), and their performance was tested with the Mann Whitney analysis.

The tables related to each task of this battery provide (i) raw scores; (ii) percent of correct answers for each patient; (iii) the mean percentage and standard deviation of the patient control group; (iv) finally, the z scores (computed from the comparison of MU's percentage performance with the mean percentage and standard deviation of the patient control group) and related level of significance are supplied in the last two columns of each table.

5.4.2.1 Visual confrontation naming task

In a visual confrontation naming task, the group of patient controls showed a virtually comparable performance with respect to living things (87%) and man-made artefacts (94%). However, despite a generally good performance with respect to man-made artefacts of all patient controls, patient MIO had some difficulties as far as living things were concerned. Although, her inclusion in the control group gives more relevance to the sharp difference observed between MU and the patient control group (see table 15). Actually, whereas MU's performance was equivalent to that of the mean percentage of the control group with man-made artefacts (94% correct), it dropped to 31% correct with living things.

By the use of the first statistical procedure, MU's ability to name stimuli belonging to the man-made artefacts class (see table 15) was found to be virtually identical to that of the mean of patient controls ($z=0$, $p=0.5$). In contrast, his performance with living things was extremely defective ($z=-3.29$, $p<0.001$).

Table 15: Visual confrontation naming: living things vs. man-made artefacts categories

	Raw data					Percent				MU vs. patient controls				
	MU	BAI	CAL	MIO	SAR	BAI	CAL	MIO	SAR	Mean %	*sd*	MU%	z	p
LIVING	10/32	31/32	32/32	20/32	29/32	96.9	100	62.5	90.6	**87.5**	*17.1*	**31.2**	-3.29	**<0.001**
ARTEFACTS	30/32	32/32	32/32	29/32	27/32	100	100	90.6	84.4	**93.7**	*7.6*	**93.7**	0.0	**=0.5**

The sharp contrast shown by MU between living things and man-made artefacts was confirmed through an analysis of covariance, where the possible effect of confounding factors was taken into account: a main effect of the two Semantic Domains was observed in MU's performance (F=26.33; df=1; p<0.001). Furthermore, the influence on MU's overall performance of variables such as Item Familiarity (F=1.64; df=1; p>0.1), Word Frequency (F=0.73; df=1; p>=0.1) and Visual Complexity (F=0.0; df=1; p=0.1), entered as covariates in the analysis, was not statistically significant.

From the different perspective of the second statistical procedure, the performance of patient controls' was also taken into consideration, collapsing together the results for the subcategories into the two main classes of living things and man-made artefacts: it was shown by a Mann-Whitney test that patients had approximately the same behaviour with living things and artefacts (Mann-Whitney $U_{(n.=64)}$=415.5, 2-tailed p>0.1). In fact, patient MIO's performance highlighted a dissociation, with an advantage for man-made artefacts relative to living things (χ^2=7.05; df=1; p<0.01). However, MU's behaviour was highly different with respect to living things and man-made artefacts (χ^2=26.7; df=1; p<0.00001).

Therefore, an advantage for man-made artefacts was firstly observed when MU's performance was compared to that of patient controls, assuming normality in the distribution of their scores; secondly, MU's performance alone showed that his behaviour with the two categories was significantly different, while the dissociation was not observed in the patient controls group. The whole pattern of findings observed through the use of the two statistical methods provides therefore a strong support to the claim that MU's category specific deficit for living things relative to man-made artefacts is well established (62.5% difference), and not subject to influence by any of the factors held to be relevant in probing patients' semantic knowledge. The results obtained through the administration of the visual confrontation naming task replicate and strengthens those found in the previous experimental section (see 5.3.1.1).

5.4.2.2 Naming from verbal description

In naming from verbal descriptions patient controls showed some variability as regards to their individual performance. However, their performance as a group was better in the case of functional (74% correct) definitions of living things with respect to man-made artefacts (91% correct). It should be noted that also a group of 20 normal English subjects did not show any difference with the two sets of descriptions, being 88.3% correct with functional and 87.2% correct with sensory descriptions of living things. An account of the performance shown by 20 normal English subjects probed with this test is given in table 18 (data from Garrard's PhD Dissertation).

Using the first statistical procedure, MU again showed a category specific deficit, with an impaired performance with respect to living things in the case of functional definitions (28% correct). Indeed he was impaired with respect to the mean performance of patient controls ($z=-2.12$, $p<0.05$) as regard to functional descriptions (see table 16). An analysis of covariance carried out on MU's performance with functional descriptions led to a significant effect of Semantic Domain ($F=14.61$; $df=1$; $p<0.001$), confirming the advantage he showed for man-made artefacts with respect to living things. Furthermore, MU's performance in this task was not influenced by Visual Complexity ($F=0.076$; $df=1$; $p>0.5$), whereas an effect of both Item Familiarity ($F=7.05$; $df=1$; $p<0.01$) and Word Frequency ($F=10.17$; $df=1$; $p<0.005$) was found to affect his naming scores.

As a second step, the control patients' performance with functional descriptions was again taken into consideration. They showed a significant difference between living things and man-made artefacts (Mann-Whitney $U_{(n.=64)}=295.5$, 2-tailed $p<0.005$). However, looking at the data, it can be observed that MU is significantly worse on living things ($\chi^2=20.6$, $df=1$, $p<0.0001$), but so was also SAR ($\chi^2=15.1$, $df=1$, $p<0.0005$). In conclusion, MU differed from patient controls when normality in the distribution of the performance of control group was assumed. Moreover, the critical patient showed the classical dissociation between the domains of living things and man-made artefacts when his individual performance was taken into account. Similarly, the critical variable did lead to the same effect when the group of patient controls was examined separately from MU's performance, likely due to SAR's sharp dissociation between the two categories.

Therefore, in the case of naming from verbal functional descriptions, MU's specific deficit for living things was unclear when the findings from the second statistical method were examined. However, the first statistical procedure provides evidence of a robust dissociation in MU's behaviour, even if the group of patient controls showed a significant effect in the same direction as MU, an effect which might be accounted by the variability in control patients across categories.

Table 16: Naming from functional verbal descriptions: living things vs. man-made artefacts categories

	Raw data					**Percent**				**MU vs. patient controls**				
	MU	**BAI**	**CAL**	**MIO**	**SAR**	**BAI**	**CAL**	**MIO**	**SAR**	**Mean %**	*sd*	**MU%**	z	p
LIVING	9/32	28/32	31/32	20/32	16/32	87.5	96.9	62.5	50	**74.2**	*21.7*	**28.1**	-2.12	**<0.05**
ARTEFACTS	27/32	32/32	31/32	24/32	30/32	100	96.9	75	93.7	**91.4**	*11.2*	**84.4**	-0.62	**>0.1**

It has to be observed that with sensory descriptions patient controls' performance with respect to both domains was quite similar (76% correct with living things and 75% correct with artefacts). However, MU showed only a mild dissociation across categories (31% correct with living things; 53% correct with man-made artefacts).

Using the first statistical procedure, patient MU was also defective with respect to patient controls ($z=-2.79$, $p<0.005$) in naming the same set of living stimuli described through their sensory properties (see table 17). As in the case of functional descriptions, a significant main effect of Semantic Domain was observed in MU's performance with respect to sensory definitions ($F=6.72$; $df=1$; $p<0.05$). Frequency influenced MU's performance with sensory descriptions ($F=8.50$; $df=1$; $p<0.005$), while Item Familiarity ($F=0.14$; $df=1$; $p>0.5$) and Visual Complexity ($F=0.04$; $df=1$; $p>0.5$) did not lead to any significant effect on his performance.

In contrast to the previous findings, MU's ability to name man-made artefacts from functional verbal definitions was highly comparable to patients controls (see table 16). However, MU's performance with respect to sensory definitions of man-made artefacts ($z=-1.41$, $p>0.05$) showed a trend to significance (see table 17 and comments just below). Therefore, the role of confounding factors on MU's performance with man-made artefacts was again assessed through an analysis of covariance. While an effect of Item Familiarity was observed to influence MU's performance on functional descriptions naming ($F=4.75$; $df=1$; $p<0.05$), no effect of this factor was found as regard to sensory descriptions ($F=2.55$; $df=1$; $p>0.1$); moreover, both word frequency and visual complexity did not affect significantly MU's performance, both on functional (Frequency: F=0.082; df=1; p>0.5; Visual Complexity: F=1.32; df=1; p>0.1) and sensory verbal descriptions (Frequency: F=2.22; df=1; p>0.1; Visual Complexity: F=0.14; df=1; p>0.5) of man-made artefacts.

Table 17: Naming from sensory verbal descriptions: living things vs. man-made artefacts categories

	Raw data					Percent				MU vs. patient controls				
	MU	BAI	CAL	MIO	SAR	BAI	CAL	MIO	SAR	Mean %	*sd*	MU%	z	p
LIVING	10/32	29/32	29/32	20/32	20/32	90.6	90.6	62.5	62.5	**76.5**	*16.2*	**31.2**	-2.79	**<0.005**
ARTEFACTS	17/32	28/32	27/32	17/32	24/32	87.5	84.4	53.1	75	**75**	*15.5*	**53.1**	-1.41	**>0.05**

The second statistical procedure was then performed on patient controls' performance with sensory definitions. Their behaviour highlighted that no differences are shown by patients with respect to the two categories (Mann-Whitney $U_{(n.=64)}=495$; 2-tailed p>0.5). However, MU's individual performance with living things and man-made artefacts was not as striking as usual ($\chi^2=3.1$, df=1, p>0.05).

Therefore, although the data can be generally considered in favour of the dissociation between the two semantic domains, MU's individual performance shows that, when administered with sensory descriptions, his difficulties involve both the categories of living things and man-made artefacts. Although the use of the second statistical method provided unclear results, the strong effect shown by the use of the first statistical procedure leads to the conclusion that MU's categorical deficit for living things is quite robust. In conclusion, a category specific deficit for living things was observed in patient MU also in the verbal description naming task, when confronted to the mean performance of the patient control group. His knowledge of the living things class was disrupted when he was provided with definitions stressing both functional and sensory attributes. This result provides further support to the findings described in the previous experimental section (5.3.1.2).

Furthermore, in the present section the potential effect of confounding variables such as word frequency, item familiarity, and visual complexity on MU's performance in this task was examined. To summarise, visual complexity was found to be a factor that never influenced MU's performance, regardless domains or type of verbal description. However, word frequency was found to be relevant as far as sensory and functional descriptions about living things were concerned. Familiarity instead influenced MU's performance on functional descriptions with respect to the category of man-made artefacts.

Table 18: Naming after verbal descriptions: mean percentage of correct responses given by 20 English normal subjects

	Functional descriptions	**Sensory descriptions**
	Mean Percent *(sd)*	**Mean Percent** *(sd)*
LIVING	88.3 *(15.5)*	87.2 *(15.6)*
ARTEFACTS	90.5 *(11.5)*	82.1 *(17.2)*
Animals	91.4 *(8.9)*	93.9 *(8.9)*
Birds	98.8 *(3.7)*	90.8 *(12.6)*
Fruits-veg.	71.3 *(19.5)*	70.3 *(16.9)*
Household/utensils	91.2 *(12.3)*	76.9 *(16.8)*
Vehicles	88.4 *(8.6)*	97.6 *(4.9)*

Normative data from Peter Garrard's PhD Dissertation

5.4.2.3 Categorisation task

In the categorisation task, the patients had to classify the whole set of stimuli presented visually into living things and man-made artefacts. The patient control group did not show any difference between man-made artefacts (92% correct) and living things (94% correct) categories. However, in this task MU was 81% correct with the living things class (see table 19), and the first statistical procedure showed that his performance was poorer with respect to that of the patients' group (z=-2.83, p<0.005). However, no differences between the critical patient (94% correct) and the control patients (92% correct) were observed as respect to man-made artefacts (table 19).

Table 19: Categorisation of living things vs. man-made artefacts categories

	Raw data					Percent				MU vs. patient controls				
	MU	BAI	CAL	MIO	SAR	BAI	CAL	MIO	SAR	Mean %	*sd*	MU%	z	p
LIVING	26/32	31/32	30/32	28/32	31/32	96.9	93.7	87.5	96.9	**93.7**	*4.4*	**81.2**	-2.83	**<0.005**
ARTEFACTS	30/32	30/32	30/32	28/32	30/32	93.7	93.7	87.5	93.7	**92.1**	*3.1*	**93.7**	0.5	**>0.1**

Therefore, MU's category-specific deficit for the living things class was observed also in the categorisation task based on the two main domains of living things and man-made artefacts.

5.4.2.4 Sorting by categories

The sorting task required patients to sort the whole set of visually presented stimuli into the main domains of living things and man-made artefacts.

Patient controls were generally good in sorting at the category level. Using the first statistical procedure, MU's ability to sort visually presented stimuli into living things (72% correct) and man-made artefacts (100% correct) categories indicated a deficit for living things in this patient (z=-1.75; p<0.05) with respect to the control group, whereas he was normal in the case of artefacts (table 20).

Table 20: Sorting by living things and man-made artefacts categories

		Raw data					Percent				MU vs. patient controls				
		MU	BAI	CAL	MIO	SAR	BAI	CAL	MIO	SAR	Mean %	*sd*	MU%	z	p
Categories	LIVING	23/32	32/32	32/32	32/32	24/32	100	100	100	75	**93.7**	*12.5*	**71.9**	-1.75	**<0.05**
	ARTEFACTS	32/32	31/32	32/32	29/32	32/32	96.9	100	90.6	100	**96.9**	*4.4*	**100**	0.7	**>0.1**

A related pattern of results was again observed using the second statistical procedure. When the performance within patient controls was compared across conditions, it showed that controls are virtually identical with respect to the two categories (Mann-Whitney $U_{(n.=64)}$=448, 2-tailed p>0.1). However, when MU's performance was considered, he was impaired in the case of living things relative to man-made artefacts (χ^2=10.1, df=1, p<0.005), providing further evidence that his performance was clearly different from that of the other HSE patients, who all performed almost at ceiling.

The examination of the main findings, therefore, seems to corroborate also in this task the presence of a dissociation in MU's performance, characterised by a deficit affecting living things relative to man-made artefacts. This conclusion is strongly supported firstly by the difference between MU and the patients group when an assumption of normality in the distribution scores of the controls is made. Secondly, by the observation of no significant effect of category type on the control patients' performance when it was considered separately; thirdly, by the presence of a significant difference in MU's behaviour only, with respect to the two classes of stimuli.

5.4.2.5 Word-to-picture matching task

In a word-to-picture matching task, MU was extremely defective (50% correct) with living things stimuli, whereas his ability (97% correct) was virtually identical to that of patient controls (98% correct) with man-made artefacts (see table 21). In fact, using the first statistical procedure, his performance with the living things class was defective with respect to the mean score of patient controls ($z=-7.6$; $p<0.0001$). The performance of the whole group of patients was then examined by the use of the second statistical procedure, and they showed a virtually identical performance with the two domains of living things and man-made artefacts (Mann-Whitney $U_{(n.=64)}=494.5$; 2-tailed $p>0.5$). However, if the performance of patient MU was examined singularly, he was clearly defective with living things ($\chi^2=18$, $df=1$, $p<0.00005$), showing that his performance was clearly different from that of the patient controls.

Table 21: Word-to-picture matching of living things and man-made artefacts categories

	Raw data					Percent				MU vs. patient controls				
	MU	BAI	CAL	MIO	SAR	BAI	CAL	MIO	SAR	Mean %	*sd*	MU%	z	p
LIVING	16/32	32/32	32/32	28/32	30/32	100	100	87.5	93.7	**95.3**	*6*	**50**	-7.6	**<0.0001**
ARTEFACTS	31/32	32/32	32/32	31/32	30/32	100	100	96.9	93.7	**97.6**	*3*	**96.9**	-0.25	**>0.1**

As observed in the previous tasks of this battery, also in the case of a matching task converging evidences are provided by the different statistical methods adopted. MU showed an advantage for living things with respect to man-made artefacts both when normality in the distribution of scores in the control patients was assumed and when his performance was examined separately from that of the other HSE patients. In addition, the performance of the control group did not lead to statistically significant effects with respect to the two semantic domains. These observations provide further evidence of the dissociation between categories described in the first experimental section (section 5.3).

5.4.2.6 Assessment of semantic knowledge of subcategories of living things and man-made artefacts

For the naming tasks, it is useful to examine the previous findings from the perspective of individual subclasses of stimuli. In order to verify whether MU's impairment with living things involved selective subclasses of items, or was instead a deficit affecting all subcategories to a similar extent, the performance of the whole group of HSE patients was examined in detail with respect to each of the tasks comprising this battery. The relevant findings are presented below, and the tables related to the data discussed in this section are in appendix A.

Visual confrontation naming of subcategories of living things and man-made artefacts

As far as the man-made artefacts subcategories were concerned, they were found to be essentially unaffected, with MU completely comparable to the performance obtained by the mean of patient controls (see table 1, appendix A). When animals, birds and fruits/vegetables were taken into consideration (see table 1, appendix A) using the first statistical procedure, an impairment affecting all subclasses massively was however observed in MU's performance (animals: $z=-3.56$, $p<0.0005$; birds: $z=-2.37$, $p<0.01$; fruits/vegetables: $z=-4.44$, $p<0.0001$).

When MU's performance over the whole set was considered, a difference between subclasses was also observed in an analysis of covariance (main effect for Subclass: $F=6.59$; $df=4$; $p<0.001$). However, no main effect of Subclass was found when living things (F=0.103; df=2; p>0.5) and man-made artefacts (F=0.36; df=1; p>0.5) subcategories were considered separately, showing that the items belonging to each of the two main semantic domains were broadly comparable in MU's performance. Furthermore, no influence on MU's naming performance of all three factors was found with respect to subcategories of living things (Familiarity: F=1.15; df=1; p>0.1; Frequency: F=0.46; df=1; p>0.5; Visual Complexity: F=0.16; df=1; p>0.5), and the same was also true for man-made artefacts subclasses (Familiarity: F=0.12; df=1; p>0.5; Frequency: F=0.14; df=1; p>0.5; Visual Complexity: F=0.0; df=1; p>0.5). In conclusion, the three factors of item familiarity, word frequency, and visual complexity showed no effect on MU's performance on visual confrontation naming, both when the main domains, and the subclasses of living things and man-made artefacts were examined. However, the significant main effect of Semantic Domains highlighted MU's differential behaviour with respect to man-made artefacts and living things. In addition, no effect was found of subclasses pertaining to each of the two domains when entered separately in the analysis. In general, no effect of different subclasses of stimuli was found in MU's performance, indicating a general disruption of his ability to name visually presented stimuli belonging to the living things domain.

Naming of subcategories of living things and man-made artefacts after verbal descriptions

MU's performance with respect to subclasses of living things and man-made artefacts was compared to that of patient controls by the use of the first statistical procedure. In both functional and sensory descriptions the subclasses of animals (functional descriptions: z=-3,6; p<0.0005; sensory descriptions: z=-3.17; p<0.001) and birds (functional descriptions: z=-2.71; p<0.005; sensory descriptions: z=-2.71; p<0.005) were severely defective in MU, whereas he was not significantly different from patient controls with the subclass of fruits/vegetables. However, in the case of fruits and vegetables, the lack of and effect might be due to a very large standard deviation in the patient controls group (see tables 2 and 3, appendix A). When the effect of confounding factors regarding subcategories of living things was considered through an analysis of covariance, MU's performance with respect to either types of verbal descriptions was only influenced by Word Frequency (functional descriptions: F=7.27; df=1; p<0.01; sensory descriptions: F=13.2; df=1; p<0.001), while no significant effect was found both for Item Familiarity (functional descriptions: F=3.29; df=1; p>0.05; sensory descriptions: F=0.048; df=1; p>0.5) and Visual Complexity (functional descriptions: F=0.0; df=1; p=0.1; sensory descriptions: F=0.018;

df=1; p>0.5).

Then MU and patient controls' performance was taken into account with respect to the subcategories of household items and vehicles: the first statistical procedure showed that MU was not different from patient controls in the naming from functional definition task (see table 2, appendix A), with a trend to a significant difference, however, in the case of household items (z=-1.39; p=0.08). His performance with respect to sensory descriptions did not differentiate from that of the patient group as far as vehicles were concerned, but MU showed an impaired performance (z=-1.9; p<0.05) relative to sensory descriptions of household items (see table 3, appendix A). The influence of Word Frequency (F=0.08; df=1; p>0.5) and Visual Complexity (F=1.32; df=1; p>0.5) on MU's performance regarding functional descriptions of man-made artefacts subcategories did not led to statistically significant effects. However, the patient's performance on this set of definitions was significantly influenced by Item Familiarity (F=4.75; df=1; p<0.05). In the case of sensory description none of the three factors considered affected MU's performance (Frequency: F=2.22; df=1; p>0.1; Familiarity: F=2.55; df=1; p>0.1; Visual Complexity: F=0.14; df=1; p>0.5)

The possibility of internal differences between subcategories belonging to either the semantic class of living things or man-made artefacts was also assessed. However, a main effect of Subclass was not found in MU's performance with respect to both functional and sensory descriptions of animals, birds and fruits/vegetables, when an analysis of covariance was performed on his scores (functional descriptions: F=0.75; df=2; p>0.5; sensory descriptions: F=1.59; df=2; p>0.5). An absence of effect of Subclasses was also found to be non significant both in the case of functional (F=2.5; df=1; p>0.1) and sensory descriptions (F=0.56; df=1; p>0.1) of household items and vehicles. This result demonstrates that each of the subcategories pertaining to either one of the two main classes of living things and man-made artefacts was not different from the others belonging to the same semantic domain.

Furthermore, when subclasses of the living things domain were taken into consideration, he was impaired with respect to animals and birds, but he was not significantly different from patient controls with the fruits/vegetables subcategory. In contrast, his ability to deal with man-made artefacts was generally spared both with respect to functional and sensory definitions, although a tendency toward a deficit was observed in the case of sensory descriptions. This trend was in effect more evident when subcategories belonging to the man-made artefacts class were examined: in the case of sensory descriptions. MU had a performance which did not differ from that of patient controls in the case of vehicles, but he was significantly worse than the patient control group with household/utensils items.

In general, MU's selective deficit for subclasses of living things was observed also in naming from verbal descriptions, except for fruits and vegetables, where the controls had a very large standard deviation. This result, although not straightforward as in the case of the visual confrontation naming task, provides however support to the original findings observed in section 5.3.1.2.

5.4.3 Summary

HSE patients' knowledge associated to two classically investigated semantic categories, living things and man-made artefacts, was probed through the use of a battery of tasks specifically devised in the attempt to tap different aspects and modalities of conceptual knowledge, and replicate the findings presented in the previous experimental section (5.3).

In the present investigation, a quite generalised pattern of impairments affecting the living things class and related subcategories tends to emerge in patient MU on a wide array of tasks of this battery, in front of a highly comparable performance between him and the group of patient controls as respects to man-made artefacts and associated subclasses (see table 22).

The comparison of MU's performance on two naming tasks, that examined in the previous experimental section (5.3.1.1) and the one presented in this second investigation (section 5.4.2.1), demonstrates as his performance in both naming tasks is quite similar. MU was 33 % correct in the first naming task (section 5.3.1.1.) with living things, and 31% correct in the present one (section 5.4.2.1). In the first experimental section, he showed 45% difference between man-made artefacts, which were unimpaired, and living things, that were instead affected; in the present investigation the difference between semantic domains was even larger (62% difference). In visual confrontation naming also three subclasses of living things, animals, birds and fruits/vegetables are defective (section 5.4.2.6), being instead preserved patient's semantics of man-made artefacts and their subcategories (see table 1, appendix A, for a full account of the patient's performance).

On functional description naming (section 5.4.2.2), MU shows a defective performance with respect to living things (28% correct), as was also observed in a comparable task in the previous experimental section (5.3.1.2), where MU was only 35% correct. However, in the case of man-made artefacts patient MU's performance is well preserved (91.4% correct) with respect to functional descriptions (section 5.4.2.2), a result that is comparable to that found in the previous experimental section (5.3.1.2), where the patient was 80% correct in this task, showing no difference as regard to patient controls in both sections. Furthermore, in the actual investigation MU's performance is comparable to that of patient controls only in the case of fruit subclass, due to a very large variability in the patient controls group.

However, his naming performance with respect to sensory descriptions (section 5.4.2.2) highlights a generalised decay. Even though living things (31% correct) are affected to a comparable extent as in visual confrontation and in functional verbal description naming (see figure 8), a considerable decrease, although not significant, is also present as respect to man-made artefacts (53% correct), where household items in particular (section 5.4.2.6) are significantly affected (46% correct). In the previous section (5.3.1.2), MU was only 20% correct with sensory descriptions of living things, but not significantly different from patient controls; moreover, though his performance with man made artefacts was only 65% correct, he was not significantly different with respect to patient controls. Therefore, the present sensory description task (section 5.4.2.2) allows the emergence of a category specific deficit which was not observed in the same type of task (section 5.3.1.2) in the previous experimental section.

In the present investigation, MU's categorisation skills (5.4.2.3) are also found to be impaired in the case of the main category of living things. This finding is important since it is not predicted by Tyler et al.'s (in press) assumption that in the case of little task demands, as in the case of categorisation, a deficit affecting the living things class should not be observed.

Moreover, in this second assessment, MU's semantic comprehension of living things (50% correct) in comparison to that associated to man-made artefacts (97% correct) proved to be severely affected also in a word-to-picture matching task (section 5.4.2.5), where the patient's performance completely overlaps that probed through the visual confrontation naming task (see table 22). The same basic result was observed in the first experimental section (5.3.1.4), where a deficit selectively involving living things (61% correct) was observed in a word-to-picture matching task, leaving instead man-made artefacts knowledge unaffected (100% correct).

In the sorting task (section 5.4.2.4) MU's deficit for living things arises when the broad categories of living things (72% correct) and man-made artefacts (100% correct) are examined.

Therefore, if the two main categories of living things and man-made artefacts are taken singularly into account, a category specific deficit affects MU's living things knowledge across the majority of tasks presented in this experimental section. The most frequently impaired subclasses within the living things domain are those of land animals and birds, whereas MU's ability to perform with knowledge of fruits is only occasionally impaired (see table 22). As discussed above in detail, the findings described in the first experimental investigation of a category specific deficit selectively affecting the living things category, are clearly replicated in this section. Furthermore, the adoption of a series of tasks wider than that used in the previous investigation allowed the examination of MU's semantic knowledge about living things and man-made artefacts domains on a finer detail.

In the following section, the second purpose of this experimental investigation will be addressed, through the assessment of MU's semantic knowledge associated to "mass" stimuli. This attempt was made in order to better determine the extent of patient MU's semantic loss about "mass" categories and to evaluate their relation with respect to the living things class.

Table 22: MU's performance, contrasted with the mean scores obtained by patient controls, in the basic battery for the assessment of living things and man-made artefacts knowledge

TASKS	LIVING	ARTEFACTS	Animals	Birds	Fruit/veg.	Household	Vehicles
Visual Confrontation Naming	$\underline{\times\ p<.0001*}$	$\underline{=\ p=.5}$	× $p<.0005$*	× $p<.01$*	× $p<.0001$*	= $p>.1$	= $p>.1$
Functional descriptions	× $p<.05$*	= $p>.1$	× $p<.0005$*	× $p<.005$*	= $p>.1$	= $p>.5$	= $p>.1$
Sensory descriptions	× $p<.005$*	≭ $p>.05$	× $p<.001$*	× $p<.005$*	= $p>.05$	× $p<.05$*	= $p>.1$
Categorisation	× $p<.005$*	= $p>.1$					
Sorting by category	$\underline{\times\ p<.05*}$	$\underline{=\ p>.1}$					
Word-to-picture matching	$\underline{\times\ p<.0001*}$	$\underline{=\ p>.1}$					

*×: significantly worse than controls; =: comparable to controls; ≭= tendency toward a deficit; *=significantly worse than controls.*
For the two main domains, the convergence between findings obtained by different statistical methods is underlined.

5.4.4 Basic battery for the assessment of semantic knowledge of "mass" categories

A series of tasks, involving "mass" stimuli was devised in order to achieve a more comprehensive depiction of MU's behaviour with respect to this semantic category than it was possible in the first experimental section. More importantly, the examination of MU's behaviour with "mass" stimuli can provide further insight with respect to the relation between living things and "mass" categories. The number of tasks employed was wider than that previously used in this work (section 5.3). None of the other HSE patients was available at the time of testing in order to participate to this second assessment of "mass" knowledge. However, MU's performance in this battery was confronted to that of five normal subjects, matched to the patient for age, education and sex (see table 23). The normal subjects group underwent the testing following the same procedure adopted to assess MU's knowledge. Furthermore, a group of 50 normal subjects (see table 24) subdivided into groups of 10 —half males and half females— according to their age, were asked to rate on a five points scale the familiarity of a much wider number of stimuli (118 items), and a final set of 40 stimuli, highly counterbalanced by word frequency and item familiarity, was finally adopted (see table 25).

Table 23: Description of 5 normal subjects used as controls to patient MU

N. of subjects	Education	Sex	Age Mean and range
5	13	M	31.2 range 30-33

Table 24: Description of 50 normal subjects who were asked to score the familiarity of the entire items set

N. of subjects	Education Mean and range	Sex		Age Mean and range
10	15.9 range 13-19	5 M	5 F	24.8 range 21-27
10	16.4 range 13-24	5 M	5 F	33.4 range 30-38
10	14.3 range 8-23	5 M	5 F	44.4 range 40-49
10	9.8 range 5-16	5 M	5 F	54.1 range 50-59
10	9.6 range 5-19	5 M	5 F	65.3 range 60-76

In order to verify whether the stimulus set adopted for this battery was comparable in terms of word frequency and item familiarity with respect to the three categories of substances, liquids and materials, an analysis of variance was performed on the mean values reported in table 25. Neither Frequency (F=0.93; df=2; p>0.1) nor Familiarity (F=1.13, df=2; p>0.1) resulted different as regards to the three subclasses of "mass" stimuli. Moreover, a further control was made to ascertain whether the "mass" set of stimuli was comparable in terms of frequency and familiarity to those related to living things and man-made artefacts used in the preceding battery (table 14, section 5.4.2). An analysis of variance, carried out on the frequency and familiarity norms associated to the three main domains of living things, man-made artefacts and "mass" items, showed that the three sets were comparable both in terms of Word Frequency (F=0.62; df=2; p>0.5) and Item Familiarity (F=4.3; df=2; p>0.5).

Table 25: Mean and sd of familiarity and frequency norms

		Frequency		**Familiarity**	
	N. of items	**Mean**	*sd*	**Mean**	*sd*
Whole set	40	2.14	*1.50*	1.18	*0.23*
Substances	16	1.71	*1.28*	1.25	*0.24*
Liquids	8	2.04	*1.54*	1.18	*0.26*
Materials	16	2.61	*1.64*	1.11	*0.21*

Familiarity and frequency normative data were transformed into natural log, in order ensure their joint use in further analysis. Frequency norms for Italian written words were taken from the Dizionario di Frequenza della Lingua Italiana C.N.R., Roma

Each task of the battery involved the same set of 40 stimuli (a list of the item set is presented in appendix C), divided into three main categories, namely, edible substances (16 items, e.g. cocoa, mayonnaise, grana cheese, roasted beef,), liquids (8 items, e.g. red wine, lemonade) and materials (16 items, e.g. copper, emerald, wool, cork). [In order to better devise some of the tasks, the three categories could be furthermore divided into subcategories of 4 items each, comprising: (i) powder sauces, (ii) creamy sauces, (iii) cheeses and (iv) meats as respects to the main category of edible substances; (i) alcoholic drinks and (ii) non alcoholic drinks as far as liquids were concerned; (i) metals, (ii) precious stones, (iii) textiles and (iv) "other" materials for the class of materials]. Stimuli were coloured 10×15 cm pictures taken by a professional photographer from real substances, liquids and materials. The three main categories of stimuli, edible substances, liquids and materials were as much as possible counterbalanced by the two factors of familiarity and frequency (table 25).

The battery (tasks are listed in appendix C) comprised: (i) a visual confrontation naming task; (ii) four word-to-picture matching tasks differing in terms of relative difficulty; (iii) two sorting tasks in which the task demand was manipulated. In the visual confrontation naming task stimuli were presented visually to the patient one at a time in random order. In the case of matching tasks, two of them employed inter-categorical distractors: the first task adopted distractors belonging to the three main categories and 8 alternatives were presented in each foil, being this task the most similar to that adopted in the previously described battery. The second used distractors belonging to all 10 subcategories: in each trial the target had to be chosen between 4 alternatives. The other two matching tasks used instead extra-categorical distractors: in the first, distractors were visually similar to the target and the patient had to choose within each foil between 4 alternatives; in the second, distractors visually dissimilar with respect to the target were selected, and a choice between 8 alternatives had to be made in each trial. Two sorting tasks were also devised: in the first one the patient had to sort the item set into three categories: edible substances, liquids and materials (first level sorting). The second one forced the patient to sort the stimulus set into 10 subcategories (second level sorting).

In all the tasks stimuli were presented randomly and the patient had unlimited time in order to provide a response. He could examine each item as long as he needed and was allowed to correct himself whenever he was unsure about his first answer. Only the responses the patient was absolutely certain of underwent scoring. Patient MU was tested for about an hour a week and each of the tests was presented in different sessions, in order to avoid habituation to the stimulus set and more general effects of practice. As outlined above, five normal subjects, used as controls to MU's performance, were administered with the entire set of tasks of the battery, and the procedure adopted in MU's case was the same in the case of the control group.

The tables related to each task of this battery present (i) MU's raw data; (ii) MU's percent of correct answers; (iii) the mean percentage and standard deviation of the normal control group; (iv) the z scores (computed from the comparison of MU's percentage performance with the mean percentage and standard deviation of the normal subjects group) and the related level of significance.

5.4.4.1 Visual confrontation naming task

In the visual confrontation naming task patient MU was extremely impaired as respect to the whole set of items (25% correct), and he was well below the mean percentage of the normal controls (z=-33.2; p<0.0001). His performance (see table 26) was very poor indeed relatively to all the three main categories (substances: 25%; materials: 18.7%; liquids: 37.5% correct). When his performance was confronted to that of the normal controls group, MU was highly impaired in the case of all categories of substances (z=-25; p<0.0001), liquids (z=-5.6; p<0.0001) and materials (z=-23; p<0.0001).

In order to verify the possible influence of items frequency and familiarity on MU's naming performance, an analysis of covariance was performed on his scores related to the whole item set. Remarkably, both Familiarity (F=0.003, df=1, p=0.96) and Frequency (F=0.52, df=1, p=0.94) were found to have <u>no</u> effect on patient's performance. In addition, a main effect of Semantic Class was not observed (F=0.892, df=2, p=0.42), leading to conclude that the three sets were quite comparable.

Table 26: Visual confrontation naming tasks on "mass" categories

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	10/40	25	94.5	*2.1*	-33.2	**<0.0001**
Substances	4/16	**25**	**95**	*2.8*	-25	**<0.0001**
Liquids	3/8	**37.5**	**87.5**	*8.8*	-5.6	**<0.0001**
Materials	3/16	**18.7**	**97.5**	*3.4*	-23	**<0.0001**

Therefore, MU's ability to deal with stimuli belonging to the "mass" semantic category was extremely affected in a visual confrontation naming task. This result shows the same tendency observed in MU's performance on the visual confrontation naming task for substances, liquids and materials described in the first experimental investigation (section 5.3.1.1).

5.4.4.2 Word-to-picture matching tasks

The analysis of MU's performance in the series of word-to-picture matching tasks showed a general pattern of decreasing difficulty from the two inter-categorical tasks towards the extra-categorical tasks. The first inter-categorical matching task (see table 27) was the most similar to that of the basic battery for the assessment of living things and man-made artefacts knowledge (section 5.4.2.5): MU had to choose the target between 8 highly visually similar alternatives. He generally found difficulties in this task (37.5% correct over the whole set; 37.5% with substances; 31.2% with materials and 50% with liquids). Therefore, when his performance was compared to that of five normal subjects, MU was found to be severely impaired with all subclasses taken as a whole (z=-27.3; p<0.0001), and more specifically with substances (z=-17.5; p<0.0001), liquids (z= nc, p= indeterminate) and materials (z=-24.1; p<0.0001).

Table 27: Inter-categorical matching task with 8 alternatives

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	15/40	37.5	98.5	*2.2*	-27.3	**<0.0001**
Substances	6/16	37.5	97.5	*3.4*	-17.5	**<0.0001**
Liquids	4/8	50	100	*0*	nc	**indet.**
Materials	5/16	31.2	98.7	*2.8*	-24.1	**<0.0001**

In the second inter-categorical matching task (see table 28), however, despite the visual similarity of distractors was high as in the previously described matching task, the reduced number of alternatives, 4 in the latter case, likely lowered the task demands. Therefore, MU's performance increased to some extent (50% correct over the whole set; 62.5% with substances; 37.5% with liquids and 43.7% with materials). However, the comparison of MU's performance to that of normal subjects showed that the patient was nonetheless poorer than the control group both in the case of the whole set of "mass" stimuli (z= nc, p= indeterminate) and with the three classes of substances (z=-13; p<0.0001), liquids (z=-10.7; p<0.0001) and materials (z=-15.7; p<0.0001).

Table 28: Inter-categorical matching task with 4 alternatives

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	20/40	50	97.5	*0*	nc	**indet.**
Substances	10/16	62.5	98.7	*2.8*	-13	**<0.0001**
Liquids	3/8	37.5	97.5	*5.6*	-10.7	**<0.0001**
Materials	7/16	43.7	97.5	*3.4*	-15.7	**<0.0001**

Visual discriminability between items seemed to play a major role in MU's performance also in the case of both extra-categorical matching tasks. MU enhanced his scores in the first extra-categorical matching task, where distractors were highly different from one to the other (see table 29: 77.5% correct over the whole set; 81.2% with substances; 75% correct with materials and liquids). However, MU's performance remained well below the mean percentage of normal controls both with respect to the entire item set (z=-15.7; p<0.0001) and with substances (z= nc, p= indeterminate), liquids (z=-2.92; p<0.005) and materials (z= nc, p= indeterminate).

Table 29: Extra-categorical matching task: highly different distractors and 4 alternatives

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	31/40	77.5	99	*1.37*	-15.7	**<0.0001**
Substances	13/16	81.2	100	*0*	nc	**indet.**
Liquids	6/8	75	95	*6.8*	-2.92	**<0.005**
Materials	12/16	75	100	*0*	nc	**indet.**

In contrast, in the second extra-categorical matching task, when distractors were chosen on the basis of their high similarity to the target, despite coming from different categories (see table 30), MU's performance (42.5% correct over the whole set; 43.7% with substances and materials; 37.5% with liquids) dropped to levels comparable to those observed with the inter-categorical matching tasks. MU's impairment could also be observed when his scores were compared to those of the normal control group (whole set: z=-40.9; p<0.0001; substances: z=-19.7; p<0.0001; liquids: z=-8.4; p<0.0001; materials: z= nc, p= indeterminate).

Table 30: Extra-categorical matching task: slightly different distractors and 8 alternatives

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	17/40	42.5	98.5	*1.37*	-40.9	<0.0001
Substances	7/16	43.7	98.7	*2.8*	-19.7	<0.0001
Liquids	3/8	37.5	95	*6.8*	-8.4	<0.0001
Materials	7/16	43.7	100	*0*	nc	indet.

A brief examination of MU's performance in a series of matching task showed how his defective comprehension of the semantic category of "mass" items was widespread, in particular in comparison to the mean performance of a group of five normal subjects of his age, sex and education.

5.4.4.3 Sorting tasks

The first sorting test administered to the patient was based on the three subcategories of substances, liquids and materials (first level sorting). In this test MU was generally good (see table 31), both when his performance was considered overall and when the three groups of "mass" categories were separately examined (97.5% correct over the whole set; 100% with substances and liquids; 93.7% with materials). This result was confirmed also by the comparison of MU's performance to that of the normal controls group, where, although he was found to be defective over the whole item set ($z=-1.79$; $p<0.05$) and with the class of materials ($z=-1.79$; $p<0.05$), the patient's performance was however equal to that of normal subjects with respect to substances (z= nc; p= indeterminate) and liquids ($z=+0.45$; $p>0.1$).

Table 31: Sorting task by three categories

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	39/40	97.5	99.5	*1.12*	-1.79	**<0.05**
Substances	16/16	100	**100**	*0*	nc	**indet.**
Liquids	8/8	100	**97.5**	*5.6*	0.45	**>0.1**
Materials	15/16	93.7	**98.7**	*2.8*	-1.79	**<0.05**

When MU was subsequently asked to sort the item set over the 10 subcategories belonging to the three main sets (table 32), he found increasing difficulties with respect to the previous sorting task —probably because of the enhanced number of alternative possibilities he had to consider in order to perform the task— (see table 32). When MU's responses in this task were collapsed over the three main categories, a deficit was evident as regards to the whole set of items (52.5% correct), substances (62.5% correct), liquids (50% correct) and materials (43.7% correct). The increasing difficulty of this task was also demonstrated by the comparison of MU and normal subjects' performance, where MU showed a very poor performance with respect to the whole set (z=-33.6; p<0.0001), substances (z= nc, p= indeterminate), liquids (z=-6.2; p<0.0001) and materials (z= nc, p= indeterminate).

Table 32: Sorting task by all categories

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Whole set	21/40	52.5	98.5	*1.37*	-33.6	**<0.0001**
Substances	10/16	62.5	**100**	*0*	nc	**indet.**
Liquids	4/8	50	**92.5**	*6.8*	-6.2	**<0.0001**
Materials	7/16	43.7	**100**	*0*	nc	**indet.**

MU's impairment of "mass" semantic knowledge was highlighted also by the examination of his performance in two sorting tasks. Even though he showed an enhancement in performance as far as the fist sorting task is considered (table 31), possibly due to the decrease in the task demands, his ability to deal with different subcategories of substances, liquids and materials was found to be very poor (table 32), leading to errors which were, on the whole, refusals to assign a given picture to a subcategory, because he "did not know where to put it or what the picture was about".

5.4.5 Summary

An assessment of patient MU's categorical knowledge associated to different types of "mass" items was performed through the use of a battery of tasks as much as possible comparable to those comprising the battery presented in the previous experimental part (section 5.3) and assessing the knowledge of living things and man-made artefacts. The three item sets of substances, liquids and materials were comparable in terms of familiarity and frequency norms. The whole array of tasks was administered only to patient MU and to a group of five normal subjects, since the HSE patients group was not available at the time of testing.

A generalised impairment, affecting about to the same extent three categories, edible substances, liquids and materials, is shown by patient MU in comparison to normal subjects' performance on the large majority of tasks administered (see figure 9), with the exception of the first level sorting task. MU's visual confrontation naming performance (section 5.4.4.1) is extremely defective as regards to all three categories, being 25% correct with substances, 37.5% correct with liquids and 19% correct with materials, and thus sharply differing from the mean performance of normal controls. Notably, in the present investigation (section 5.4.4) neither word frequency nor item familiarity are found to influence patient's performance in the naming task, providing support to the robustness of the finding (section 5.4.4.1). Noteworthy, the present results represent a good replication of the findings described in the first experimental section (5.3), where MU's naming performance with the "mass" category (section 5.3.1.1) was highly defective with respect to substances (0% correct), liquids (17% correct) and materials (22% correct).

A pattern of impairment comparable to that observed in the naming task is found also in the case of a series of word-to-picture matching tasks (section 5.4.4.2): the most severely affected are those matching tasks whose number of alternatives was higher (see tables 27 and 30); moreover, the presence of visually similar distractors leads to a decrease in MU's performance (tables 27 and 28). Therefore, whenever it is found, an enhanced performance (table 29) seems to be mainly attributable to differences in the task demands and to relative discriminability of the stimuli. Despite the differences between different versions of matching tasks, however, patient MU is highly defective with respect to the mean performance of normal subjects.

MU's is shown to be sensitive to task difficulty also in two sorting tasks (section 5.4.4.3): in fact, the patient is flawless in a sorting tests requiring to decide among three alternatives (1st level sorting), as shown also by his good performance with respect to normal subjects in the case of substances (100% correct) and liquids (100% correct). However, the patient is much more defective on a second sorting task (52.5% on the whole item set), where, at variance, he has to consider a higher number of alternatives (2nd level sorting).

5.4.6 General conclusion

MU's knowledge of two classical semantic domains, living things and man-made artefacts, and that of a novel semantic category, "mass", was ascertained in detail through the administration of two basic batteries assessing categorical knowledge. A wide series of tasks, as much as possible comparable between batteries, was presented to patient MU. As far as the basic battery for the assessment of living things and man-made artefacts is considered, a category-specific deficit for living things arises in MU's performance in contrast to patient controls over a large array of tasks (section 5.4.2). A widespread impairment related to three classes of "mass" items (section 5.4.4.), such as substances, liquids and materials, is also found in this patient when confronted to the mean performance of a group of normal subjects. Although a direct comparison of MU's performance to that of patients controls could not be performed on visual confrontation naming tasks of living things and "mass" categories, since the HSE patients controls were not administered with the battery assessing "mass" knowledge, an examination of MU's performance over these categories is however plausible. The consideration of MU's performance from a single case perspective, with respect to living things, man-made artefacts and "mass" categories, puts in evidence an extremely similar pattern of impairments and preservations over the highest comparable, although not identical, tasks of the two batteries, namely, (i) visual confrontation naming (section 5.4.2.1 for living things and artefacts and section 5.4.4.1 for "mass" items); (ii) word-to-picture matching with 8 alternatives and visually similar distractors (section 5.4.2.5 for living things and artefacts and section 5.4.4.2 for "mass" items); (iii) sorting by semantic categories (section 5.4.2.4 for living things and artefacts, and section 5.4.4.3 for "mass" items). This comparison was made possible by the fact that the three semantic domains do not differ in terms of frequency and familiarity norms.

Table 33: Comparison between MU's performance with living things, man-made artefacts and different classes of "mass" stimuli in comparable tasks

TASKS	Artefacts	Living things	Mass
Visual confrontation naming	= $p=.5$	× $p<.0001$*	× $p<.0001$*
Word-to-picture matching	= $p>.1$	× $p<.0001$*	× $p<.0001$*
Sorting by categories	= $p>.1$	$\times\!\!\!\!=$ $p>.05$	× $p<.05$*

*×: worse than controls; =: comparable to controls; $\times\!\!\!\!=$= tendency toward a significance; *=significantly worse than controls*
NB: controls are HSE patients in the case of artefacts and living things, and normal subjects in the case of "mass" kinds; the tasks, although similar, are not identical.

As discussed above, in this experimental section (5.4) the sets of living things, man-made artefacts and that of "mass" stimuli were matched by familiarity and frequency, and, more importantly, they did not lead to statistical differences between semantic categories, which could be considered equal in terms of these basic variables (see section 5.4.4).

Therefore, a closer examination of MU's performance on different visual confrontation naming tasks was possible. It can be observed (see figure 10) how living things (31% correct) and three categories of "mass", substances (25% correct), liquids (37% correct) and materials (19% correct), are all damaged with respect to MU's performance on man-made artefacts (94% correct). It is also worth to stress that MU's scores are not influenced by the effect of confounding factors such as frequency and familiarity, both in the case of living things and artefacts classes (section 5.4.2.1), and in the case of the "mass" category (section 5.4.4.1). Considering MU's performance with respect to living things, man-made artefacts and "mass" kinds as if the findings were obtained in two following sessions, in the first investigation MU was 33% correct with living things, 0% with substances, 17% with liquids, 22% correct with materials and finally 75% correct with artefacts. The confrontation of these results to those described in this second experimental section highlights the similarity of the findings between the two testing sessions. This pattern adds indeed new consistency to the basic framework of findings observed in the first experimental section (5.3), where the original idea was firstly tested.

The same picture arises when MU's performance on the most similar matching tasks of the two batteries (inter-categorical matching with 8 alternatives and visually similar distractors) is examined. In contrast to an almost perfect performance with man-made artefacts (97% correct, section 5.4.2.5), MU (see figure 11) is clearly impaired both with respect to living things (50% correct, section 5.4.2.5) and three classes of "mass" items (section 5.4.4.2), namely substances (37% correct), liquids (50% correct) and materials (31% correct).

In the sorting by semantic categories tasks, MU has an enhancement in performance with respect to living things (72% correct), and shows a ceiling performance (100% correct) with man-made artefacts subclasses (section 5.4.2.4). MU's performance is also good in the case of the three "mass" categories (section 5.4.4.3), being 97.5% correct with the whole set of stimuli, although he results significantly worse than normal controls.

As a whole, these results substantiate the findings described in the first experimental section (5.3). Moreover, this replication is much more a robust finding, insofar as a wider series of tasks was employed in assessing MU's categorical knowledge of both living things and "mass" kinds. Moreover, measures of familiarity and frequency were adopted for both the living things and man-made artefacts categories and the "mass" set, in order to control for the influence of these factors, which resulted not to affect MU's naming performance in the case of all three main semantic domains. Therefore, some link seems to intertwine living things and "mass" domains, suggesting the likelihood of a substantial similarity in the processing underlying the semantics of these conceptual categories. However, in order to achieve a better framework of the relation between living things and "mass" categories, a detailed examination of the role of functional and sensory properties of the two key classes of concepts is needed. This question is pursued in the following experimental section, through the adoption of two different types of tasks, feature generation and feature verification tasks.

5.5 Assessment of semantic attributes knowledge of living things, man-made artefacts and "mass" categories

5.5.1 Introduction

The third part of the present work was aimed at assessing the knowledge patient MU has of semantic properties associated to living things, man-made artefacts and "mass" kinds.

In this section, the study of semantic memory organisation is then pursued from a different perspective. In fact, in their original account of the category specificity phenomenon Warrington and Shallice (1984) hypothesised the fundamental role of functional and sensory properties for the distinction between members within a semantic category. The authors emphasised the importance of functional relative to sensory information in the case of man-made artefacts, while they proposed that living things are primarily differentiated in terms of their sensory features with respect to functional ones. However, the influence of different sources of semantic information as regards to the knowledge of semantic domains such as living things, man-made artefacts and "mass" items, has not been so far thoroughly clarified. The specific aim of this experimental section was therefore pursued through the use of two types of tasks, both tapping semantic attribute knowledge, but basically differing in their approach at the assessment.

The spontaneous production of semantic information about a large number of living things, man-made artefacts and "mass" items was firstly investigated through the adoption of an attribute generation procedure. In this task patients were orally presented with a series of words referring to either living things or man-made artefacts in a first session (5.5.2), and to "mass" items in a subsequent testing session (5.4.4); patients had to describe each of the items as exhaustively as they could, and their oral responses were transcript by the examiner. Patients were quite free to provide oral descriptions of items, without any specific constraint. Their production of semantic details, however, was constantly encouraged, because they often tended to provide highly sketchy descriptions of the stimuli. More specifically, they were indirectly ("What is the general category of this item?"; "This item can..."; "This item has..."; "This item is...") driven to provide information about the category to which an item belongs, functional features, sensory attributes of the stimulus, and encyclopaedic information about the concept, such as associative and contextual information. This procedure was the same adopted by Garrard et al. (unpublished) for the collection of their featural database about living things and artefacts. The only difference between the procedure followed in this work and that of Garrard's is that in the latter case experimenters presented subjects with written words, and required them to answer in the written modality.

MU's performance was confronted to that of four HSE patient controls in the attribute generation task concerning living things and man-made artefacts (section 5.5.2). Unfortunately, when "mass" knowledge was probed with the same paradigm (section 5.5.4), only patient MU underwent testing. Thus his performance had to be compared to that of 10 closely matched normal subjects.

The second task assessed patients' knowledge of semantic properties of the same set of 64 living things and man-made artefacts stimuli (section 5.5.6), used in the previous feature generation paradigm, on a quite different perspective. It has to be noted that in the case of "mass" stimuli (section 5.5.8), the feature verification task employed a subset of 40 items, taken from the larger set of 118 stimuli used in the spontaneous production task. In order to prepare this features verification task, a featural database related to the three main domains of interest was collected from normal population. In the case of living things and man-made artefacts, the featural database collected by Garrard et al. (unpublished) was employed. As briefly outlined above in this section, Garrard and co-workers asked 20 normal English subjects to provide in a written form a series of semantic information about each of the items presented. Subjects were required to supply category, encyclopaedic, functional and sensory information about the items in the same unconstrained way already described before ("What is the general category of this item?"; "This item can..."; "This item has..."; "This item is..."). Subsequently, the descriptions provided by the experimental subjects were examined and classified into four semantic information types. Finally, each item was associated to a series of semantic features, which formed the final database which was employed in the present work (see appendix D). Exactly the same procedure followed by Garrard and colleagues was adopted for the collection of a featural database about the "mass" category. In this case, 10 Italian normal subjects were asked to provide descriptions of 118 "mass" items and the semantic features associated to each stimulus, previously classified in terms of information type, concurred to form the "mass" featural database (see appendix D). Subsequently, feature-item pairs were presented to patients, who were asked to judge whether a semantic feature pertained or not to a given item. It is worth noting that each feature-item pair for which the answer had to be ''no'', involved only plausible pairs, in which the feature did not pertained to the item, but was typical of other items belonging to the same general semantic domain. A more detailed description of the task procedure will be provided in section 5.5.6 as far as living things and artefacts are concerned, and in section 5.5.8 in the case of "mass" stimuli.

In the feature verification task the performance of MU, patient controls and also that of 25 normal subjects was assessed as regards to living things and man-made artefacts (section 5.5.6); however, only the performance of patient MU and that of a group of 5 normal subjects was examined in the case of "mass" items (section 5.5.8), since the patient control group was not available when the testing was carried out.

The two tasks, the attribute generation and the feature verification tasks are quite different one from the other, both in terms of the procedure adopted to build and administer the test and in the modalities followed to collect and classify patients' answers, which could lead to some defects that were, as far as possible, taken under control.

Actually, two major problems could affect the findings related to the attribute generation task: in this case patients' descriptions of concepts could be sometimes highly idiosyncratic or difficult to categorise. Moreover, each description had to be classified into four different types of information, namely category, encyclopaedic, functional and sensory semantic attributes: this procedure could be however prejudiced by the criterion adopted by the examiner for classification. For this reason, very strict criteria were used to identify the four types of semantic information from patients' spontaneous descriptions of concepts. The semantic attributes produced by patients were therefore designated as an instance of category, encyclopaedic, functional or sensory information according to the following criteria: category features were those that placed the item in a superordinate category (e.g.: "a cat is an animal"; "a hammer is a tool"; "wood is a material"). Encyclopaedic information described some type of contextual or associative relationship (e.g. "a tiger is found in India"; "the chisel is used to make statues"; "grana cheese is found in food stores"); this type of information was therefore disentangled from the general concept of functional property. Functional features were those which described an action, activity or use of an item (e.g. "a cat can catch mice"; "a knife can cut things"; "tea can be drunken"): in this latter case, however, a difficulty arose in the definition of the notion of function, since, in the case of man-made artefacts and, to some extent, of "mass" items, it directly addresses to the "use" of objects, though in a less refined way in the case of materials; in contrast, when living things are concerned, it tends to indicate "what an animate thing can do". However, this cannot be as straightforward in the case of fruits and vegetables, since exemplars of this subclass of living things point more directly toward a definition of function in terms of "the use we make of the item". Finally, sensory information was that which could be appreciated in some sensory modality (e.g. "a leopard has a fur coat"; "an axe is heavy"; "emerald is green"). However, while man-made artefacts tend to immediately suggest information related to the shape an object has, in the case of living things and "mass" kinds, other types of information seem to be much more prominent, such as colour and texture. These criteria were the same adopted to realise the two semantic feature databases used to devise the attribute verification tasks. The adoption of this methodology was thought to grant for both types of tasks, at least to some extent, a general agreement on what is meant by different types of semantic attributes.

In the second task, patients' knowledge of semantic attributes was probed through the evaluation of patients' ability to make judgements about the appropriateness of a semantic feature with respect to a given item. The procedure of providing patients with feature-item pairs, however, enhances greatly the amount of semantic information available to the patient in order to make a decision. Hence, although for patients with semantic deficits this task might be easier to perform than the attribute generation task, in which semantic knowledge has to be spontaneously retrieved, it might also lead to biased findings. Therefore, a loss in patients' semantic knowledge, even though already shown through the use of other tasks, might perhaps be hidden in the feature verification task, because of the high amount of semantic information the patient has been made available. However, the use of the same *a priori* criteria concerning the classification of semantic features (produced by patients in the first task and provided to patients by the examiner in the second task), and the adoption of the same set of stimuli, might allow a better control of the findings resulting from the administration of these two tasks.

From the observations made in this section, a quite intriguing problem arises: the notions related to functional and sensory properties are by no means easily interpretable. Therefore, comments about the findings related to the variability of these notions in different domains will be provided later in the following sections. It is however acknowledged that a finer discrimination of the meaning of these two types of semantic information is needed in order to avoid misunderstandings relative to the findings from patients' performance. Therefore, a finer attempt towards this direction will be performed in the fourth experimental section (5.6) of this work.

5.5.2 Generation of semantic attributes of living things and man-made artefacts

A first semantic attribute generation task, concerning the classical domains of living things and man-made artefacts, was based on the set of 62 items used by Peter Garrard et al. (unpublished)[2] both for the basic battery for the assessment of semantic knowledge described in section 5.4.2, and to build the featural database which will be more thoroughly described later in section 5.5.6. The stimulus set comprised 30 living things, further subdivided into 16 animals, 8 birds and 6 fruits/vegetables, and 32 man-made artefacts, distinguished into 16 household/utensils, 8 tools and 8 vehicles (the stimulus set is listed in appendix D).

HSE patients were orally asked to provide semantic information about each item of the stimulus set. Patients were given unlimited time in order to provide an exhaustive description of the concept, and they were allowed to rearrange or change their definitions until they were satisfied about the description they had made. Given the large amount of time required to collect data from patients, a range of 3-4 sessions of testing was necessary for each patient, in order to prevent stereotyped responses and to avoid losing their collaboration. Patients were tested weekly for an hour per session, and were allowed to stop about every 10 minutes. Unfortunately, patient MIO refused to complete the task; hence the performance of only three patient controls (CAL, SAR and BAI) and that of the critical patient MU was examined. Patients' production of semantic attributes was classified by two independent judges as pertaining to four classes of semantic information, namely, category, encyclopaedic, functional and sensory information on the basis of the criteria outlined in the introduction (section 5.5.1). Only the semantic properties that were homogeneously classified by the two judges as belonging to a given type of semantic information underwent the analysis, and therefore any kind of definition which was difficult to classify or contained idiosyncratic information (e.g.: chicken "I like it only when it is cooked"; saw: "it can be used to cut my wife's head") was expunged. The analysis of data followed the two general procedures outlined in the methodological section (5.2): first, MU's scores were compared to those of controls, assuming the normality in the distribution of responses given by controls. Secondly, an item by item analysis, carried out on the proportions of functional and sensory features, provided by the control group for each

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[2] I am grateful to Dr. Peter Garrard and co-workers for having made available their featural database in order to accomplish the purposes of the present study.

of the items belonging to the semantic categories under investigation, was performed by the use of the Wilcoxon test. MU's individual performance was tested separately, following the same procedure adopted with controls. Tables from 34 to 36 provide (i) the raw number of semantic attributes given by each patient for each of the four types of semantic information; (ii) the percentage proportion of each type of information, calculated over the total number of semantic properties generated by each of the patients; (iii) the ratio between proportions of functional vs. sensory features produced by patients; (iv) the mean percentage proportion and standard deviation for each type of information and for the functional/sensory ratio, calculated on the basis of the mean percentage proportion performance of the three patient controls; (v) the z score and level of significance resulting from the comparison of the mean percentage proportion of patient controls and MU's percentage proportion performance.

5.5.2.1 Production of semantic attributes of living things and man-made artefacts categories

Production of semantic attributes of the whole set of stimuli

By the adoption of the first statistical procedure, it was shown that MU's ability to provide semantic information about the whole set of stimuli used in this task (see table 34) was in general comparable to that of the mean performance of patient controls as far as category and encyclopaedic information is considered; however, he produced a significantly higher proportion (41.5%) than the patient controls (29%) of functional information ($z=+1,92$; $p<0.05$), but he was defective (17%) with respect to the patient controls group (31%) when asked to produce sensory information ($z=-1,96$; $p<0.05$). The ratio between proportion of functional and sensory features produced by MU was 2.5, highlighting a clear difference between his behaviour and that of the patient controls group ($z=+6.84$; $p<0.00001$; see table 34).

Comparing the performance of patient controls with respect to their production of functional and sensory attributes, a second statistical procedure was carried out over items by the Wilcoxon test. It was shown that they generated an equivalent proportion of functional and sensory features (Wilcoxon test over items: $z=-0.23$; 2-tailed p>0.5) However, MU's production of the two types of features was significantly different (Wilcoxon test over items: z=-4.12; 2-tailed p<0.00001). This result also shows that MU's behaviour was quite divergent from that of the other patient controls.

Table 34: Production of semantic attributes: whole item set (z and p refer to proportions of different feature types)

	Category		Encyclopaedic		Functional		Sensory		Ratio F/S
	Raw data	%	Raw data	%	Raw data	%	Raw data	%	
Bai	57	9.2	193	31	203	32.6	169	27.2	1.2
Cal	36	10.1	152	42.8	74	20.8	93	26.2	0.79
Sar	29	8.8	65	19.6	107	32.3	130	39.3	0.82
Mean %		**9.4**		**31.1**		**28.6**		**30.9**	**0.94**
sd		*0.7*		*11.6*		*6.7*		*7.3*	*0.23*
MU	**22**	**9.1**	**79**	**32.8**	**100**	**41.5**	**40**	**16.6**	**2.5**
z		-0.4		0.14		1.92		-1.96	6.84
p		**>0.1**		**>0.1**		**<0.05**		**<0.05**	**<0.00001**

Therefore, from the analysis of the production of semantic attributes over the whole item set, a peculiar phenomenon is highlighted in MU. In contrast to patient controls, who do not show this effect, the critical patient is much better in generating functional than sensory features, and this behaviour is corroborated by the use of two different statistical procedures which lead to convergent and robust findings.

Production of semantic attributes of living things

When patients' performance with living things was examined with the first statistical procedure (see table 35), no differences were found between patient controls and MU in providing category, encyclopaedic and sensory information, while he generated a higher proportion of functional information than the controls (z=+1,92; p<0.05). If MU's ability to provide functional vs. sensory information is taken into account singularly, it can be however observed as he could give 40.7% of functional information, in contrast to 15,7% of sensory features. The ratio between functional and sensory attributes generated by MU was 2.59, showing that his performance was highly different from that of patient controls (z=+6.35; p<0.00001, see table 35). The patient control group, instead, produced a similar proportion of sensory (28%) and functional (24%) information (ratio functional/sensory: 0.9, see table 35). By the use of the second statistical procedure, the comparison of the performance of the patient controls group with respect to the production of functional and sensory features was carried out through the Wilcoxon test over items. Their performance with the two types of features was not significantly different (Wilcoxon test over items: z=-1; 2-tailed p>0.1). When MU's performance was separately examined, he showed to produce significantly more functional than sensory attributes of living things (Wilcoxon test over items: z=-3; 2-tailed p<0.005), indicating that his performance was really different from that of the other patients.

Table 35: Production of semantic attributes: living things (z and p refer to proportions of different feature types)

	Category		Encyclopaedic		Functional		Sensory		Ratio F/S
	Raw data	%	Raw data	%	Raw data	%	Raw data	%	
Bai	30	9.5	101	32.1	99	31.4	85	27	1.16
Cal	28	17.4	83	51.5	24	14.9	26	16.1	0.92
Sar	18	11	36	22.1	42	25.8	67	41.1	0.63
Mean %		**12.6**		**35.2**		**24**		**28.1**	**0.9**
sd		*4.2*		*14.9*		*8.4*		*12.5 #*	*0.26*
MU	**18**	**16.7**	**29**	**26.8**	**44**	**40.7**	**17**	**15.7**	**2.59**
z		0.97		-0.56		1.99		-0.99	6.35
p		**>0.1**		**>0.1**		**<0.05**		**>0.1**	**<0.00001**

#: task insensitive: The patient controls range is such that MU cannot perform 2 sd below the controls mean

These findings provide evidence of a dissociation in MU's performance with respect to functional and sensory semantic features. Therefore, converging data come from different statistical methods when the generation of attributes of living things is examined, providing strong support to the basic results observed when the whole set of items was taken into consideration.

Production of semantic attributes of man-made artefacts

Within the domain of man-made artefacts (see table 36), the first statistical procedure was initially adopted. Looking at the proportion of features produced, MU scored at a comparable rate with respect to patient controls in relation to category, encyclopaedic and functional information, whereas his generation of sensory attributes compared with patient controls was extremely defective (z=-3.05; p<0.005). Again, MU was much more spared in his ability to retrieve from memory functional features than sensory information (42.1% vs. 17.3% respectively). In his case, the ratio between proportions of functional and sensory attributes produced was 2.43

(z=+5.79; p<0.00001), being therefore significantly different from patient controls (see table 36). However, patient controls did not show differences in the proportion of functional (32.8%) and sensory (33.1%) information produced (ratio functional/sensory: 1). By the use of the second statistical procedure, the performance of the whole group of patients in the generation of proportion of functional and sensory attributes of man-made artefacts was examined. The Wilcoxon analysis over items showed that the control group as a whole had a quite comparable performance with the two attribute types (Wilcoxon test over items: z=-0.43; 2-tailed p>0.5). However, when MU's performance was examined, he was very different from patient controls, since in this latter case a significant difference between proportions of feature types was observed (z=-2.9; 2-tailed p<0.005).

Table 36: Production of semantic attributes: man-made artefacts (z and p refer to proportions of different feature types)

	Category		**Encyclopaedic**		**Functional**		**Sensory**		**Ratio F/S**
	Raw data	**%**	**Raw data**	**%**	**Raw data**	**%**	**Raw data**	**%**	
Bai	27	8.8	92	30	104	33.9	84	27.4	1.24
Cal	8	4.1	69	35.6	50	25.8	67	34.5	0.75
Sar	11	6.5	29	17.3	65	38.7	63	37.5	1.03
Mean %		**6.5**		**27.6**		**32.8**		**33.1**	**1**
sd		*2.3*		*9.4*		*6.5*		*5.2*	*0.24*
MU	4	3	50	37.6	56	42.1	23	17.3	**2.43**
z		-1.47		1.06		1.43		-3.05	5.79
p		**>0.05**		**>0.1**		**>0.05**		**<0.005**	**<0.00001**

Also in the case of man-made artefacts, the dissociation between the production of functional and sensory features was observed in patient MU. The examination of the results obtained through different statistical methods suggests that this behaviour is quite robust in the critical patient, and therefore these data are compatible with those described as regard to the whole item set and the living things category.

5.5.2.2. Production of semantic attributes of subcategories of living things and man-made artefacts

Patients' ability to provide semantic information concerning different subclasses of living things and man-made artefacts was also examined. The relevant findings are presented below in this section, and tables related to the data, from 7 to 12, are listed in appendix A. A general outline of the main results obtained by MU in this task is also shown in table 37 (section 5.5.3).

Production of semantic attributes of animals

The first statistical procedure was initially adopted. In the case of land animals (see table 7, appendix A), both MU and patient controls were comparable in producing proportions of category, encyclopaedic and sensory information. At variance, MU showed significantly greater proportions in providing functional information when compared to the performance of the patient controls group ($z=+1.88$; $p<0.05$). Once more, looking at the proportions, MU could report about 25% more semantic information related to functional aspects than to sensory attributes of animals (respectively 41.7% vs. 15%). The ratio between the proportion of functional and sensory attributes was 2.78 in patient MU (see table 7, appendix A), who was therefore significantly different from the mean functional/sensory ratio obtained by patient controls ($z=+5.08$, $p<0.00001$). Using the second statistical procedure, the Wilcoxon analysis over items highlighted MU's different behaviour with respect to the two critical feature types (Wilcoxon test over items: $z=-2.23$; 2-tailed $p<0.05$). This sharp difference between proportions of information types was not found in the case of patient controls, who provided as a group 24% information about function and 30% regarding sensory features (ratio functional/sensory: 0.84). In contrast to MU, therefore, the Wilcoxon analysis over items, showed no significant difference between proportions of functional vs. sensory features produced by the patient controls group (Wilcoxon test over items: $z=-1.19$; 2-tailed $p>0.1$).

Again, this finding is in line with the previous results described in the present section. The results obtained from different statistical treatments highlight the convergence of the data, and put in evidence the sharp difference between MU's generation of functional and sensory properties.

Production of semantic attributes of birds

By the use of the first statistical procedure, carried out on the proportions of attributes generated, it was observed that the whole group of patients was comparably capable in supplying semantic information about birds. No significant differences in performance were observed as regards to the four types of semantic information (see table 8, appendix A). It is nevertheless worth to note that MU could spontaneously retrieve a proportion of 34.8% functional properties of birds with respect to only the 8.7% of sensory attributes. The ratio between proportions of functional and sensory features produced by MU was 4, showing (see table 8, appendix A) that he was significantly different from the mean performance of the control group ($z=+6.35$; $p<0.00001$). However, using the second statistical procedure on the proportions of the critical feature types generated by MU, the Wilcoxon analysis over items did not reach significance: $z=-1.09$; 2-tailed $p>0.1$). Control patients, however, had a quite similar performance in the case of proportions of functional (24% correct) and sensory (27% correct) attributes (ratio functional/sensory: 0.98). Also in the case of control patients the second statistical procedure was adopted over proportions of attributes generated, and the Wilcoxon analysis did not highlighted any difference between functional and sensory properties (Wilcoxon test over items: $z=0$; 2-tailed $p=1$).

In the case of birds, the dissociation between functional and sensory attributes observed in MU was not consistently corroborated by the mean of different statistical procedures. However, this result might be explained by the insensitivity of the task in the case of the production of sensory attributes, due to a very large variability in the patient controls behaviour. Therefore, the basic result of an advantage in MU's generation of functional properties, although not supported by the high convergence of the two statistical methods, seems to be present also in the case of birds.

Production of semantic attributes of fruits and vegetables

Within the subcategory of fruits/vegetables (see table 9, appendix A) the first statistical procedure showed that MU was comparable to patient controls in providing details about encyclopaedic and sensory information. However the proportion of category ($z=+4.25$; $p<0.0001$) and functional information ($z=+2.92$; $p<0.005$) was greater than that of the patient controls group. Notably, a strong tendency to provide a smaller proportion of sensory information (24%) with respect to functional ones (44%) was again shown by MU. However, he did not differ significantly from patient controls (ratio functional/sensory in patient MU: 1.83; $z=+0.55$; $p>0.1$; see table 9, appendix A), although the patient control group produced a comparable proportion of attributes both in the case of functional (25%) and sensory (24%) features (ratio functional/sensory: 1.37). Using the second statistical procedure on MU's performance with proportions of the two types of properties, the Wilcoxon analysis showed only a trend to significance (Wilcoxon test over items: $z=-1.82$; 2-tailed $p>0.05$), whereas no significant difference was observed between proportions of functional and sensory features produced by patient controls (Wilcoxon test over items: $z=0.27$; 2-tailed $p>0.5$).

When the production of sensory and functional attributes of fruits and vegetables was examined, the dissociation between feature types was not supported in MU by convergent findings from different statistical treatments. However, the tendency to provide more functional than sensory features was again observed in patient MU. The lack of convergent results might be due to the very poor performance with sensory attributes shown by patient CAL, who probably enhanced the standard deviation rate of the patient controls group as a whole.

Patients' ability to generate semantic information about three subcategories of man-made artefacts also underwent investigation.

Production of semantic attributes of household items

Using the first statistical procedure, the proportion of features generated by patient MU about household items (see table 10, appendix A) was significantly smaller than that provided by the control group, both in the case of category (z=-2.54; p<0.01) and sensory information (z=-1,78; p<0.05). The whole group of HSE patients showed instead equivalent proportions of encyclopaedic and functional information (see table 10, appendix A). The pattern of performance favouring an higher proportion of functional attributes (37.1%) relative to sensory (22.6%) features (about 15% difference) was again observed in MU's case (ratio functional/sensory: 1.64). His behaviour differed significantly (z=+2.34; p<0.001) from that of patient controls, who produced broadly equal proportions with both types of information (functional: 33%; sensory: 34%; ratio functional/sensory: 0.99). However, the adoption of the second statistical procedure highlighted a non significant effect of the critical variable, both in patient MU (Wilcoxon test over items: z=-1.27; 2-tailed p>0.1) and in patient controls (Wilcoxon test over items: z=-0.63; 2-tailed p>0.5).

Despite the observation of a difference in MU's production of functional and sensory features of household items, the two statistical methods did not provide strong evidence of a dissociation. However, the first statistical procedure highlighted in MU a behaviour that was comparable to that of patient controls in the case of functional attributes, but was significantly different with respect to the patient controls group when the production of sensory features was taken into account. Although not clearly supported, a tendency favouring the generation of functional features relative to sensory ones in again present in a mild form in the critical patient.

Production of semantic attributes of tools

MU's knowledge of tools led to a defective proportion in the production of sensory features (z=-2.2; p<0.05) when compared to that of the three patient controls (see table 11, appendix A), as shown by the use of the first statistical procedure. No differences were instead observed between MU and control patients in the proportion of category, encyclopaedic and functional types of information. As in the previous findings, a 20% difference was found in MU's performance in favour of the generation of functional attributes (41.4%) with respect to sensory properties (20.7%). The ratio between the proportion of functional and sensory properties generated was 2 in patient MU (see table 11, appendix A), who showed to be significantly different from patient controls (z=+3.8; p<0.0001). However, following the second statistical procedure, the Wilcoxon analysis over items did not lead to a significant result (Wilcoxon test over items: z=-1.18; 2-tailed p>0.1). In contrast to MU, patient controls provided a comparable amount of functional (32%) and sensory (35%) information (ratio functional/sensory: 0.93; see table 11, appendix A). Furthermore, by the use of the second statistical procedure on the patients' proportions of functional and sensory features produced, no significant difference was observed between different types of attributes (Wilcoxon test over items: z=-0.84; 2-tailed p>0.5).

Despite the first analysis highlighted MU's different behaviour with respect to the generation of functional and sensory properties of tools, and the ratio examination led to a significant difference between the patient and the control group, the second statistical method provided results that were not consistent with the previous findings, minimising the strength of the effect.

Production of semantic attributes of vehicles

The production of semantic information related to vehicles was finally taken into exam (see table 12, appendix A). In this case, using the first statistical procedure, it was found that MU's proportion of category and encyclopaedic information produced was similar to that of patient controls. However, an higher proportion of functional attributes (z=+3.93; p<0.0001) was provided by MU with respect to control patients (see table 12, appendix A), in contrast with an impoverished performance with sensory information (z=-6.6; p<0.0001). In fact, he could retrieve in proportion 50% of functional properties, while his production decayed to 7.1% with sensory information (ratio functional/sensory: 7), being therefore significantly different from patient controls (z= +30.9; p<0.00001). This finding was also supported by the second statistical procedure, performed on MU's proportions of different attribute types (Wilcoxon test over items: -2.37; 2-tailed p<0.05). The group of patient controls generated instead a similar proportion of features, both in the case of functional (32%) and sensory (29%) information, leading to a ratio functional/sensory of 1.11 (see table 12, appendix A). Furthermore, the adoption of the second statistical procedure confirmed the results (Wilcoxon test over items: z=-1.12; 2-tailed p>0.1).

In the case of vehicles, a strong convergence of the findings obtained through the adoption of the two statistical procedures was observed. The presence of a dissociation in MU's production of functional and sensory attributes was confirmed, providing support to the results observed with both the living things and the man-made artefacts categories as a whole.

5.5.3 Summary

The first semantic attribute generation task was administered to HSE patients in order to verify the status of their semantic knowledge of concepts relating to living things and man-made artefacts, when asked to spontaneously produce different types of information about each item.

From a general perspective (see table 37), the proportion of category information produced by MU is usually similar to that of patient controls, with the exceptions of an enhanced ability to generate category information in the case of fruits/vegetables and a defective production as regards to household. As far as encyclopaedic information is concerned, MU always shows to produce an equal proportion of features with respect to patient controls in the case of all semantic categories and subcategories of items, with the exception of fruits and vegetables. In this last case, the task was insensitive, due to the large variability in the performance of the patient controls group.

However, a quite different picture is observed when patient controls and MU have to retrieve functional and sensory features of the stimuli. When the proportion of functional features produced is taken into account, MU shows sometimes a statistically significant advantage over the mean percentage of patient controls (the whole set of items, living things, animals, fruits/vegetables and vehicles). In the remaining cases, his performance is comparable to that of the control group, provided that proportion of features is examined. The generation of sensory features leads the opposite trend to arise: MU's proportion of features generated is in some instances (the whole set, man-made artefacts, household, tools and vehicles) smaller than that of the patient controls, being instead equal to them in the remaining cases.

However, it is worth noting that, if proportions of features produced is taken into examination, in the case of living things, animals, and birds MU's performance is very poor, although not statistically different, with respect to patient controls because of the insensitivity of the task. The previous consideration leads to the observation that MU's proportion of functional features produced is in general comparable to that of patient controls, or even better than the mean performance of the control group. In particular, it should be noted that MU's performance with respect to proportions of functional attributes is almost equivalent in the case of living things (40.7%) and man-made artefacts (42.1%). Moreover, in MU a comparable performance with living things (15.7%) and man-made artefacts (17.3) is also observed in the case of the proportion of sensory attributes production. In addition, the proportion of sensory features given by MU is smaller than in the control group in all cases except fruits and vegetables, if one takes into account the fact that in three instances, namely living things, animals and birds, the task was insensitive because of the variability in the individual performances of the patient controls. This would allow concluding that no differences are observed in MU's impoverished production of (proportions of) sensory features of both living things and artefacts, a result which is in keeping with Warrington and Shallice's (1984) position.

Table 37: MU's performance in the semantic attribute generation task for living things and man-made artefacts (using proportions of each feature types)

	Category	Encyclopaedic	Functional	Sensory	Ratio F vs. S
WHOLE SET	= $p>.1$	= $p>.1$	$\underline{+\ p<.05*}$	$\underline{\times\ p<.05*}$	2.5; $p<0.00001$
LIVING	= $p>.1$	= $p>.1$	$\underline{+\ p<.05*}$	$\underline{=\ \#\ p>.1}$	2.59; $p<0.00001$
ARTEFACTS	= $p>.05$	= $p>.1$	$\underline{=\ p>.05}$	$\underline{\times\ p<.005*}$	2.43; $p<0.00001$
Animals	= $p>.1$	= $p>.1$	$\underline{+\ p<.05*}$	$\underline{=\ \#\ p>.1}$	2.78; $p<0.00001$
Birds	= $p>.05$	= $p>.1$	= $p>.1$	= # $p>.05$	4; $p<0.00001$
Fruits-veg.	+ $p<.0001$*	= # $p>.05$	+ $p<.005$*	= $p>.1$	1.83; $p>0.1$
Household	× $p<.01$*	= $p>.1$	= $p>.1$	× $p<.05$*	1.64; $p<0.001$
Tools	= $p>.05$	= $p>.1$	= $p>.1$	× $p<.05$*	2; $p<0.0001$
Vehicles	= $p>.1$	= $p>.1$	$\underline{+\ p<.0001*}$	$\underline{\times\ p<.0001*}$	7; $p<0.00001$

*+: higher proportion than controls; ×: lower proportion than controls; =: proportion comparable to controls; *: significantly worse than controls; #: task insensitive: the patient controls range is such that MU cannot perform 2 sd below the controls mean. For the whole item set, the two main domains and related subcategories, the convergence between findings obtained by different statistical methods is underlined.*

However, looking at the patient controls mean performance with respect to proportions of functional and sensory attributes production, the strikingly difference between information types is not found. Moreover, their performance is similar both in the case of living things and man-made artefacts categories (see figure 13).

From a single case perspective, however, MU's ability to spontaneously produce proportions of semantic features related to sensory knowledge is constantly defective as respects to functional properties. This tendency in favour of functional attributes is observed both in the case of the two main domains —living things and man-made artefacts— and also when the six related subcategories are taken into account (see figure 12). A brief comment might be needed regarding vehicles: MU demonstrated a very poor performance when he had to supply sensory information (7%). Although a generalised deficit was observed in the case of the whole set of man-made artefacts, his ability to provide proportions of sensory details about vehicles could be influenced by the fact that, among man-made artefacts, vehicles are the most visually complex stimuli, and this could perhaps account for his highly impoverished performance.

Therefore, minor differences arose between analysis methods for subcategories, due to the small number of items in subcategories, and perhaps also to the effect of the high demands of this task. However, the adoption of a single case perspective reveals a much more consistent pattern of regularities as regards to MU's behaviour. This was observed using both the first and, though partially, the second statistical procedures on proportions of functional and sensory attribute production. A severe impairment affects the patient's ability to retrieve sensory information relative to functional properties, regardless the semantic category or subclass considered.

This last result, therefore, seems to shed light on the types of processing preserved (functional) or impaired (sensory) in patient MU, and gives some hints on the plausibility that his loss of categorical knowledge, related to living things and "mass" kinds, could be somehow connected to the patient's selective deficit of sensory featural knowledge.

5.5.4 Generation of semantic attributes of the "mass" category

In order to have a mean of comparison of MU's ability to spontaneously provide semantic information about living things and "mass", a second attribute generation task for "mass" was devised.

A set of 118 stimuli, subdivided into 52 edible substances, 27 liquids and 39 materials was used (see appendix D). The set of "mass" was presented to 10 normal subjects who had to rate on a five-point scale the familiarity of each item (table 39). Patient MU was orally presented with a single item at a time and asked to produce as much semantic information as he was capable. Since it was not possible to test HSE patient controls on this task, 10 normal subjects, matched to MU in terms of their age, sex and education, performed the task, following the same procedure as MU (table 38).

Table 38: Description of 10 normal subjects used as controls to patient MU

N. of subjects	Sex	Education	Age Mean and range
10	M	13	30.3 range 28-33

Table 39: Mean and sd of familiarity and frequency norms

		Frequency		Familiarity	
	N. of items	Mean	*sd*	Mean	*sd*
Whole set	118	1.83	*1.58*	1.16	*0.27*
Substances	52	1.61	*1.49*	1.25	*0.24*
Liquids	27	2.08	*1.74*	1.18	*0.27*
Materials	39	1.93	*1.55*	1.04	*0.27*

Familiarity and frequency normative data were transformed into natural log, in order ensure their joint use in further analysis. Frequency norms for Italian written words were taken from the Dizionario di Frequenza della Lingua Italiana C.N.R., Roma

A considerable amount of time was needed to collect information from MU, and 6 testing sessions were necessary. Attention was put to prevent stereotyped responses: the patient was tested weekly for an hour per session, and was allowed to stop about every 10 minutes. MU's and normal subjects' production of semantic properties was examined by two independent judges: information was again classified into four classes of semantic knowledge: category, encyclopaedic, functional and sensory properties. Only the semantic attributes for which an agreement about the information type was found between the two judges underwent the analysis and idiosyncratic descriptions (e.g. plastic: "exalts my creative thinking") were not considered. As for the previous generation task (5.5.2), the data analysis was performed following two statistical procedures (see section 5.2): initially, the normality in the distribution of answers given by controls was assumed, and MU's performance was compared to the mean proportion of features provided by normal subjects. On a second step, the proportions of functional and sensory attributes produced by MU and normal controls underwent separately an item by item analysis, using the Wilcoxon test. Tables from 40 to 43 present (i) the raw number of semantic attributes generated by MU; (ii) the proportion percent of each type of information, computed over the total number of semantic properties produced by the patient; (iii) the mean proportion percentage and standard deviation for each type of information provided by 10 control subjects; (iv) the ratio between proportions of functional and sensory features produced by MU and normal subjects; (v) the z score and level of significance resulting from the comparison of the proportion of features generated by control subjects and MU.

5.5.4.1 Production of semantic attributes of "mass" kinds

MU's ability to provide four types of semantic information regarding the set of 118 "mass" stimuli was examined. Using the first statistical procedure, it can be observed that MU's proportion of sensory features produced about "mass" items was much smaller (see table 40) with respect to that of 10 normal subjects of his age, sex and education ($z=-6.87$; $p<0.0001$). On the contrary, he could generate a comparable proportion of category, encyclopaedic and functional properties, as the normal control group. It should be observed that MU's proportion of sensory attributes (15.1%) was extremely smaller with respect to functional ones (37%). However, normal subjects did not show the striking difference in the proportion of the two types of attributes as was observed in MU. The patient's behaviour with respect to the two types of properties was characterised by 22.1% difference, with a ratio between the proportion of functional and sensory features of 2.45, which highlighted (see table 40) a significant dissociation between attributes with respect to the normal subjects group (z=+6.92; p<0.0001). By the adoption of the second statistical procedure, the dissociation between feature types was found to be significant in patient MU (over-item Wilcoxon test on features: z=-3.55; 2-tailed p<0.0005). Normal controls, on the other hand, provided a proportion of 29.4% functional information with respect to sensory ones (28%), with only 1.4% difference (ratio in proportion of functional/sensory features: 1.06). By the means of the second statistical procedure, proportions of the two feature types in normal subjects were examined, but no significant difference was found in this case (over-items Wilcoxon test on features: z=-0.46; 2-tailed p>0.5).

Table 40: Production of semantic attributes of "mass" kinds by MU and 10 normal controls (z and p refer to proportions of different feature types)

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Category	22	5	**6.8**	*1.3*	-1.35	**>0.05**
Encyclopaedic	188	42.9	**35.8**	*6*	1.18	**>0.1**
Functional	162	37	**29.4**	*5.4*	1.39	**>0.05**
Sensory	66	15.1	**28**	*1.9*	-6.87	**<0.0001**
Ratio F/S		2.45	**1.06**	*0.2*	6.92	**<0.0001**

In conclusion, the presence of a consistent pattern of findings over different statistical methods allow a more wide ranging interpretation of MU's behaviour with respect to the production of functional and sensory features. The dissociation observed in the previous experimental section (5.5.2) is again found in the case of "mass" kinds, highlighting a generalised deficit in the critical patient with respect to the generation of sensory features relative to functional ones.

5.5.4.2 Production of semantic attributes of three subclasses of "mass"

MU's and the normal controls group's performance was then compared for each of the three subsets of "mass" kinds.

Production of semantic attributes of substances

The first statistical procedure was initially used to compare MU's and normal controls proportions of semantic features generated in relation to substances. As shown in table 41, MU's performance was impaired in comparison to normal controls in the production of proportions of category ($z=-1.65$; $p<0.05$) and sensory ($z=-4.71$; $p<0.0005$) information. However, he provided a higher proportion of functional information than controls ($z=+3.43$; $p<0.0005$). As previously observed with respect to the whole set of items (section 5.5.4.1), he produced a proportion of 41% of functional information, but only 13.2% of sensory features. In his case, the ratio between proportions of functional and sensory attributes was 3.1 (see table 41), highlighting a clear dissociation of MU's knowledge of these two semantic features ($z=+15.3$; $p<0.0001$) with respect to normal controls. By the use of the second statistical procedure, this finding was again observed, showing that also on an item by item basis, MU had a dissociation between the two types of properties (over-items Wilcoxon test on features: $z=-2.79$; 2-tailed $p<0.01$). This same difference between proportions in the two information types was not found however in the case of normal controls (27.2% with sensory and 27.1% with functional attributes), who had a ratio between proportions of functional and sensory attributes of 1.01. The adoption of the second statistical procedure on normal controls proportions of the two critical features led to no significant difference to arise (over-items Wilcoxon test on features: $z=-0.03$; 2-tailed $p>0.5$).

Table 41: MU's and normal controls' production of semantic attributes about substances (z and p refer to proportions of different feature types)

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Category	8	3.5	6.7	*1.9*	-1.65	<0.05
Encyclopaedic	96	42.3	39	*6*	0.55	>0.1
Functional	93	41	27.2	*4*	3.43	<0.0005
Sensory	30	13.2	27.1	*2.9*	-4.71	<0.0001
Ratio F/S		3.1	1.01	*0.14*	15.3	<0.0001

The difference in the production of functional and sensory properties was again observed with substances. The robustness of the finding is guaranteed by the strong convergence of data from the two statistical methods, and shows that the effect involves also a peculiar category of "mass" kinds, such as substances.

Production of semantic attributes of liquids

Following the first statistical procedure, it was found that MU's production of proportions of semantic attributes related to liquids was comparable to that of the normal control group in the case of category, encyclopaedic and functional information (see table 42). In contrast, a severe deficit was observed when the proportion of sensory features provided by MU was examined ($z=-3.05$; $p<0.005$) with respect to normal controls. Again, he could produce in proportion more than twice functional (34.8%) than sensory (13.4%) information. The ratio between functional and sensory features provided by MU was 2.6 (see table 42), showing a significant dissociation between attribute types ($z=+7.47$; $p<0.0001$) with respect to the normal subjects group. However, by the use of the second statistical procedure, the item by item Wilcoxon analysis on MU's performance showed only a tendency toward significance (over-items Wilcoxon test on features: $z=-1.82$; 2-tailed $p>0.05$). When the proportion of the two types of semantic properties was examined in normal subjects, however, no difference was found (functional: 25.9%; sensory: 26.8%), as shown also by the ratio on proportion of functional over sensory features (0.97). The adoption of the second statistical procedure supported this finding, highlighting no difference between proportions of the two information types in the normal controls group (over-items Wilcoxon test on features: $z=0$; 2-tailed $p=1$).

Table 42: MU's and normal controls' production of semantic attributes about liquids (z and p refer to proportions of different feature types)

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Category	8	7.1	5.7	*1.7*	0.8	>0.1
Encyclopaedic	50	44.6	41	*10.5*	0.29	>0.1
Functional	39	34.8	25.9	*7*	1.28	>0.1
Sensory	15	13.4	26.8	*4.4*	-3.05	<0.005
Ratio F/S		2.6	0.97	*0.22*	7.47	<0.0001

Although the difference between MU's production of functional and sensory features was highlighted by the first statistical analysis, the same pattern of results was not found by using the second statistical procedure. The lack of convergent findings in the case of liquids might be due to the small number of items belonging to this category, and therefore diminish the strength of the results.

Production of semantic attributes of materials

Finally, using the first statistical procedure, it was shown that the patient's performance with respect to the production of proportions of semantic attributes related to materials (table 43) was impaired only in the case of sensory features (z=-3.68; p<0.0005). In contrast, he was comparable to normal controls in the production of proportions of category and functional information. Furthermore, the production of proportions of encyclopaedic features in MU was significantly higher than that of normal subjects (z=+2.39; p<0.01). In the case of materials, MU's differential proportion of functional (30.3%) vs. sensory (21.2%) features generated was not as striking as was reported for the other categories of substances and liquids (9.1% difference). The ratio between proportions of functional and sensory information provided by the patient was in fact 1.43, highlighting that in the case of materials he was not significantly different from normal subjects (z=+0.89; p>0.1, see table 43). The adoption of the second statistical procedure showed therefore that no significant difference was present in MU's proportions of the two critical types of properties (over-items Wilcoxon test on features: z=-1.48; 2-tailed p>0.1). However, in normal subjects the difference between the proportions in the two types of attributes was almost irrelevant (4.1% difference, and a ratio between proportions of functional vs. sensory information of 1.16). In addition, in the case of normal subjects, a difference in the proportion of the two feature types was not found (over-items Wilcoxon test on features: z=-0.77; 2-tailed p>0.1).

Table 43: MU's and normal controls' production of semantic attributes about materials (z and p refer to proportions of different feature types)

	MU		MU vs. normal controls			
	Raw data	Percent	Mean %	*sd*	z	p
Category	6	**6.1**	**8.1**	*1.7*	-1.18	**>0.1**
Encyclopaedic	42	**42.4**	**29.6**	*5.4*	2.39	**<0.01**
Functional	30	**30.3**	**33.2**	*6.8*	-0.42	**>0.1**
Sensory	21	**21.2**	**29.1**	*2.1*	-3.68	**<0.0005**
Ratio F/S		**1.43**	**1.16**	*0.3*	0.89	**>0.1**

The last results show again some inconsistency between the different statistical procedures adopted. Therefore, a straightforward support to the presence of the dissociation between functional and sensory features production is not provided by the whole pattern of findings related to materials.

In general, category information about the whole stimulus set and the three categories of substances, liquids, and materials was retrieved by MU in a proportion comparable to that of control subjects, except in the case of substances, where he provided a significantly smaller proportion of information with respect to the normal controls (tables 41, 42, 43). The patient's ability to supply proportions of encyclopaedic and functional information was again comparable to that of normal controls both with the whole item set (table 40) and each of the three subclasses but materials (tables 41, 42, 43). Furthermore, MU showed significantly higher proportions than the control group in the case of encyclopaedic information about materials (table 43), and with functional information of substances (table 41). In contrast, MU was extremely poor in the ability to produce proportions of sensory information both in the case of the whole item set (table 40) and with respect to all three subcategories (tables 41, 42, and 43).

5.5.5 Summary

The patient is generally poorer than controls with respect to the total number of attributes produced about "mass" stimuli. However, his scores can be compared, following the first statistical procedure, to those of controls in terms of proportion of semantic features generated by the patient and the group of 10 control subjects. Both when the whole set of stimuli (section 5.5.4.1) and the three classes of "mass" items (section 5.5.4.2) are taken into account, MU produces a proportion of category information which is comparable to that of controls, except for substances,. However, he provides a similar proportion of encyclopaedic information as normal subjects. Furthermore (see figure 14), MU can produce a comparable proportion of functional features with respect to controls both in the case of the whole set and with the three different classes of "mass" items, showing however a significant advantage with respect to controls in the case of substances. At variance, MU's generation of sensory information was thoroughly defective in terms of proportions of features produced (see figure 14), both in the case of the whole set of items and with the subcategories of substances, liquids and materials.

Furthermore, the striking discrepancy found in MU's attribute production with respect to both living things and man-made artefacts, in favour of functional relative to sensory properties, is again observed in the task involving "mass" items. However, in the case of liquids and materials the difference in the proportions of the two critical properties is not as striking as was observed with the first statistical procedure, if the results of the second statistical procedure are taken into account. Anyway, the assumption of the normality in the distribution of scores in the normal subjects group, made in this experimental section (5.5.4), is stronger than when the same procedure was adopted with HSE patient controls in the previous attribute generation task (5.5.2). Therefore, the findings observed through the use of the first statistical procedure might be considered sufficiently reliable in accounting for MU's behaviour with "mass" kinds. MU's sensory knowledge concerning three main conceptual domains, living things, man-made artefacts and "mass" kinds, is generally defective, while his ability to retrieve from memory functional information is, in comparison, preserved. It is worth noting that no differences were observed in proportions of functional and sensory attributes production of both control groups — normal controls in the case of "mass" kinds (section 5.5.4), and patient controls with living things and man-made artefacts (section 5.5.2). Again, MU's overall performance with respect to both feature production tasks suggests some close relation between the categorical knowledge of living things and "mass" kinds, which is found to be selectively disrupted in patient MU, and his featural impairment of sensory relative to functional knowledge.

5.5.6 Feature verification task about living things and man-made artefacts

Since patients' spontaneous production of semantic information related to stimuli belonging to living things, man-made artefacts and "mass" classes was essentially poor, mainly because patients were not highly fluent and needed a lot of encouragement, a different type of task was devised, in order to decrease the task demands and improve their collaboration. As outlined in the introduction to this experimental section (5.5.1), the feature verification task for living things and man-made artefacts was developed from a featural database collected by Garrard et al. (unpublished). The authors collected from 20 normal English subjects a large set of semantic properties relative to the same set of stimuli used in the basic battery for the assessment of semantic knowledge of living things and man-made artefacts in semantic dementia patients (5.4.2). Subjects were asked to provide as many information as they could about each of 62 stimuli, 30 of them being living things (furthermore subdivided into 16 land animals, 8 birds and 6 fruits/vegetables), while the remaining 32 were man-made artefacts (16 household items, 8 tools and 8 vehicles). Subjects were encouraged to provide information about four different sources of semantic information: the category to which an item belongs, encyclopaedic information, functional, and sensory properties. The featural database underwent a series of statistical treatments in order to determine two indexes of semantic relatedness to the two main domains: dominance (the proportion of subjects who generated the attribute) and distinctiveness (the extent to which a feature allows a particular concept to be distinguished from other members of the same category). In the present investigation, the measure of distinctiveness computed by Garrard and co-workers was used to accomplish the features selection described just below. A subset of item-feature pairs, related to each of the 64 items was selected, provided that the mean and standard deviation of distinctiveness were broadly comparable according to each semantic domain, subcategories within a domain, and also to each of the four semantic information types (see table 44: sd are in parentheses). The choice to take into consideration particularly the sharedness/distinctiveness dimension of semantic features was motivated by the fact that differences were described in the literature between patients' performance with very general vs. highly specific (shared vs. distinctive, in Garrard et al.'s terms) semantic features (Tyler et al., 1996; Tyler et al., in press). Therefore, since the performance of HSE patients might be influenced by this measure of semantic relatedness, the effect of distinctiveness was analysed in the subsequent investigation.

Table 44: Mean and standard deviation *(in parentheses)* of semantic features with respect to the sharedness/distinctiveness continuum

	Shared/distinctiveness	**Category**	**Encyclopaedic**	**Functional**	**Sensory**
LIVING THINGS	**S.**	0.96 *(0.06)*	0.60 *(0.12)*	0.75 *(0.14)*	0.76 *(0.18)*
	D.	------------	0.18 *(0.08)*	0.24 *(0.12)*	0.20 *(0.11)*
ARTEFACTS	**S.**	1 *(0)*	------------	0.66 *(0.16)*	0.81 *(0.11)*
	D.	0.21 *(0.17)*	0.15 *(0.09)*	0.13 *(0.06)*	0.31 *(0.27)*
Animals	**S.**	0.88 *(0)*	0.63 *(0.13)*	0.69 *(0.14)*	0.7 *(0.15)*
	D.	------------	0.15 *(0.09)*	0.17 *(0.11)*	0.1 *(0.08)*
Birds	**S.**	1 *(0)*	0.56 *(0.06)*	0.81 *(0.11)*	0.81 *(0.19)*
	D.	------------	0.17 *(0.06)*	0.31 *(0.09)*	0.22 *(0.08)*
Fruits-veg.	**S.**	1 *(0)*	0.63 *(0.14)*	--------------	0.78 *(0.19)*
	D.	------------	0.22 *(0.08)*	--------------	0.27 *(0.08)*
Household	**S.**	------------	------------	------------	------------
	D.	0.21 *(0.17)*	0.07 *(0.02)*	0.08 *(0.03)*	0.21 *(0.23)*
Tools	**S.**	1 *(0)*	------------	0.66 *(0.16)*	------------
	D.	------------	0.17 *(0.06)*	0.13 *(0)*	0.54 *(0.29)*
Vehicles	**S.**	1 *(0)*	------------	------------	0.81 *(0.11)*
	D.	------------	0.20 *(0.11)*	0.18 *(0.06)*	0.17 *(0.06)*

Data provided by Garrard et al., unpublished

The selected set of semantic features was then translated in Italian and item-feature pairs were transformed into singular very simple questions which implied a yes/no answer; each feature related to an item was therefore coupled with another feature, comparable in terms of distinctiveness level, which was plausible but not pertinent to that item (e.g.: category: "is the eagle a bird?" / "is the saw a vehicle?"; encyclopaedic: "are monkeys found in Africa?" / "is the hammer used to cut wood?"; functional: "can the frog jump?" / "can the screwdriver be used for watering plants?"; sensory: "is banana yellow?" / "is the fork very heavy?"). This procedure was adopted in order to present patients with a series of questions which led to the same probability of answering with yes or no (chance level: 50%). Table 45 provides an outline of the number and distribution of questions over (i) the two general domains of living things and man-made artefacts, (ii) their related subcategories; (iii) the four different types of semantic information.

Table 45: Number of questions for both semantic domains, related subcategories, and for each type of semantic information

	Category	Encyclopaedic	Functional	Sensory
LIVING	180	360	240	360
ARTEFACTS	180	180	240	240
Animals	60	120	120	120
Birds	60	120	120	120
Fruits/veg.	60	120	0	120
Household	60	60	60	60
Tools	60	60	120	60
Vehicles	60	60	60	120

The test was administered to the HSE patients group (MU, BAI, CAL, MIO, SAR) and also to 25 Italian normal subjects, divided in subgroups of five. Each subgroup of normal subjects was closely matched to each of the HSE patients, according to sex, age and years of schooling (see table 46).

Table 46: Description of the 25 normal subjects used as controls for each of the HSE patients group

	N. of subjects	Education	Sex	Age Mean and range
MU's normal controls	5	13	M	30 range 29-32
BAI's normal controls	5	5	F	50 range 48-52
CAL's normal controls	5	8	M	60.6 range 58-63
MIO's normal controls	5	3.6	F	72 range70-74
SAR's normal controls	5	5	M	56 range 54-58

The question set was then presented orally in a random sequence to patients and normal control subjects. Given the high number of questions, 1140 for living things and 840 for man-made artefacts, the test was administered to patients in about 7-8 subsequent sessions, each of them lasting about 1 hour, with a week of distance between sessions, in order to avoid fatigue and diminish the rate of stereotyped answers. Patients were allowed to take about six breaks during each testing session, whenever the patient required it. Three sessions were instead adequate for normal subjects in order to complete the test; each session lasted about 2 hours, and normal subjects were allowed to take a break whenever they needed it. The statistical treatment of data involved two different procedures, as described in the methodological section 5.2. The first statistical procedure compared MU's performance to the mean performance of either patients or normal controls, assuming the normality in the distribution of the scores in both control groups. A second statistical procedure was then adopted: patient controls performance was tested using the Mann Whitney analysis over items, with respect to the critical categories of living things and man-made artefacts and the semantic features examined. MU's performance with respect to the critical variable and the semantic properties considered was tested separately from patient controls by the use of the χ^2 analysis. Tables from 47 to 56 provide: (i) the percent of correct answers given by each patient; (ii) the mean percentage and standard deviation of correct answers provided both by the group of normal subjects and the patient controls group; (iii) z scores and related levels of significance were then calculated, in order to compare MU's performance with that of the mean percentage of the two control groups, normal subjects and patient controls. In a final section (5.5.6.6), MU's performance and that of the two control groups was examined with respect to subcategories belonging to the two main domains of living things and man-made artefacts, for each of the semantic attributes taken into account. In appendix A, tables from 13 to 17 present the data related to the patients and normal subjects performance with the different subcategories.

5.5.6.1 General knowledge of living things and man-made artefacts categories

Using the first statistical procedure, when the general domains of living things and man-made artefacts were considered (see table 47), MU's performance was significantly defective when compared to that of normal subjects, with no evidence of categorical effects. When MU's performance was instead evaluated in contrast to the mean percentage of patient controls, a deficit affecting the living things domain (57.2% correct) was observed ($z=-6$; $p<0.0001$), in contrast to a performance comparable to that of patient controls as regards to man-made artefacts (88.2% correct).

Table 47: Semantic knowledge of living things and man-made artefacts categories

Domain	%	MU vs. normal controls				%				MU vs. patient controls			
	MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	57.2	**98.8**	*0.6*	-69.3	**<0.0001**	93.2	94.1	82.1	90.4	**89.9**	*5.5*	-6	**<0.0001**
ARTEFACTS	88.2	**98.3**	*0.7*	-14.4	**<0.0001**	93.6	94.4	67.3	90.5	**86.4**	*12.9*	0.1	**>0.1**

Examining the performance of the group of patient controls with respect to the two main conditions of living things and man-made artefacts by the use of the second statistical procedure, a Mann-Whitney test over items showed that their performance was broadly uniform (Mann-Whitney test over items: $U_{(n=62)}=363$; 2-tailed $p>0.5$). However, MU's performance had a strikingly different behaviour with respect to the two conditions ($\chi^2=24.2$, df=1, $p<0.00001$) when considered separately from that of the patient controls group.

MU's general knowledge of the two critical semantic classes is clearly deviant from the distribution of patient controls scores, when normality is assumed. Moreover, he shows the classical dissociation between living things, impaired, and man-made artefacts, unaffected, when his individual performance is examined. In contrast, no difference between semantic categories is observed in the patient controls group behaviour when it is considered separately. In addition, looking at the data in table 47, patient controls seem to be slightly better on living things relative to man-made artefacts. Therefore, a strong dissociation between the two semantic domains is clearly suggested by the convergence between the results of different statistical procedures.

The knowledge patients have of distinctive features of items vs. those shared among different exemplars of the main domain has been also examined (table 48). By the adoption of the first statistical procedure, it was found that MU was generally poorer with respect to normal subjects, except in the case of shared features of man-made artefacts. When his performance was contrasted to that of patient controls, a deficit affecting the living things category was present, in the case of distinctive ($z=-8.78$, $p<0.0001$) and shared features ($z=-8.16$, $p<0.0001$) as well. However, the domain of man-made artefacts resulted totally unaffected in MU's performance, and no difference between distinctive and shared features was observed (table 48). In addition, MU's general knowledge associated to either distinctive or shared features, irrespectively to the semantic domain, was highly impaired as respect to both types of indexes (distinctive features: $z=-3.54$; $p<0.0005$; shared features: $z=-2.48$; $p<0.01$) after comparison to patient controls, an effect which is likely attributable to his extremely defective performance with the living things category.

Table 48: Semantic knowledge of living things and man-made artefacts distinctive vs. shared features

Domain	**Dist/shared**	**%**	**MU vs. normal controls**				**%**				**MU vs. patient controls**			
		MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	D	**42.5**	**98.3**	*0.9*	-62	**<0.0001**	91.9	92.9	72.3	84.8	**85.5**	*4.9*	-8.78	**<0.0001**
	S	**67.9**	**99.2**	*0.7*	-44.7	**<0.0001**	94.1	95	89.2	94.4	**93.2**	*3.1*	-8.16	**<0.0001**
ARTEFACTS	D	**83.6**	**98.2**	*0.9*	-16.2	**<0.0001**	94.4	93.7	65.5	89.3	**85.7**	*6.2*	-0.33	**>0.1**
	S	**99.6**	**98.6**	*0.9*	1.11	**>0.1**	91.6	96.2	71.7	93.3	**88.2**	*8.2*	1.4	**>0.05**
WHOLE SET	D	**65.4**	**98.3**	*0.7*	-47	**<0.0001**	93.3	93.3	68.5	87.3	**85.6**	*5.7*	-3.54	**<0.0005**
	S	**76.3**	**99**	*0.6*	-37.8	**<0.0001**	93.4	95.3	84.5	94.1	**91.9**	*6.3*	-2.48	**<0.01**

In order to further investigate whether HSE patients' performance on this task was influenced by dominance and distinctiveness measures, an analysis of covariance was performed. When the whole set of living things and man-made artefacts was considered, MU's performance was influenced at a significant level by Distinctiveness (F=41.67, df=1, p<0.005). In contrast, Dominance did not affect MU's performance over the whole set (F=0.058, df=1, p>0.5). Patient controls' performance was instead influenced by both measures (Distinctiveness: F=8.32, df=1, p<0.005; Dominance: F=9.82, df=1, p<0.005).

In a subsequent phase, the two semantic domains were taken into account separately in the analysis. An effect of Distinctiveness was found to affect MU's performance with living things (F=44.22, df=1, p<0.0001), but the same was not observed in Dominance case (F=0.12, df=1, p>0.5). When the performance of patient controls with living things was covariated by distinctiveness and dominance, the influence of both indexes was found (Distinctiveness: F=17.46, df=1, p<0.0001; Dominance: F=9.2, df=1, p<0.005). Moreover a main effect of Subclass was observed both in MU's performance (F=14.17, df=2; p<0.0001) and in the case of patient controls (F=12.22; df=2; p<0.0001), showing that their performance differed significantly in the case of subcategories of living things. In patient MU, an effect of distinctiveness, but not of dominance, was again reported as regards to man-made artefacts (Distinctiveness: F=19.67, df=1, p<0.0001; Dominance: F=0.059, df=1, p>0.5); noteworthy, subclasses of artefacts did not differ from each other in MU's performance (main effect for Subclass: F=0.67, df=2, p>0.5). As regards to man-made artefacts no significant effects were found for both measures

(Distinctiveness: F=2.03, df=1, p>0.1; Dominance: F=1.11, df=1, p>0.1) in the patient control group. Again in the latter case a main effect of Subclass related to the man-made artefacts domain was not observed (F=1.44, df=2, p>0.1).

5.5.6.2 Knowledge of category information

The feature verification task allows a further level of analysis about the knowledge related to semantic attributes of both the living things and man-made artefacts classes.

The examination of category information knowledge in MU was then performed, using the first statistical procedure, with respect to the main domains of man-made artefacts (99.4% correct) —spared both in comparison to normal subjects and patient controls— and living things (87.2% correct), which were instead defective, both when the mean performance of normal controls (z=-63.5; p<0.0001) and patient controls (z=-8.8; p<0.0001) was compared to that of MU (see table 49).

Table 49: Semantic knowledge of category information for living things and man-made artefacts categories

Domain	%	MU vs. normal controls				%				MU vs. patient controls			
	MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	**87.2**	**99.9**	*0.2*	-63.5	**<0.0001**	100	99.3	97.8	97.2	**98.6**	*1.3*	-8.8	**<0.0001**
ARTEFACTS	**99.4**	**98.5**	*1.53*	0.59	**>0.1**	86.7	97.8	68.3	88.9	**85.4**	*12.4*	1.1	**>0.1**

The second statistical procedure was then used to examine the performance of the HSE control group with respect to the living things/man-made artefacts distinction. Through the use of the Mann-Whitney test over items, a significant difference within the control patient group was found (Mann-Whitney test over items: $U_{(n.=62)}$=18.5; 2-tailed p<0.0001), indicating that their performance was dissimilar with respect to the critical categories. This finding was probably due to a general poorer performance of the patient control group with man-made artefacts relative to living things in all patients except CAL. However, if the performance of patient MU was analysed separately, a significant advantage was found for artefacts (χ^2=11.9, df=1, p<0.001), showing that his behaviour was clearly different from that of the other patients.

The examination of the findings tested through the adoption of different statistical techniques, confirms the presence of a clear dissociation between living things and artefacts in MU's semantic knowledge of category information. In fact, he showed a selective impairment of living things with respect to the patient controls when the assumption of the normality in the distribution of the patient group scores was made and when his performance was considered singularly. However, if the patient controls were examined separately from MU's behaviour, an effect of the critical variable was also observed, but the effect is clearly in the opposite direction with respect to that shown by MU, providing therefore a strong evidence of the dissociation between semantic categories in MU's knowledge of category information.

By the use of the first statistical procedure, the examination of MU's ability to deal with categorical information along the dimensions of distinctiveness vs. sharedness (see table 50), highlighted no differences within the domain of man-made artefacts, after comparison to both normal subjects and patient controls. A deficit was instead reported for MU's knowledge of shared features of living things (normal subjects: z=-63.5; p<0.0001; patient controls: z=-8.8; p<0.0001).

Table 50: Semantic knowledge of category information: distinctive vs. shared features

Domain	Dist/shared	%	MU vs. normal controls				%				MU vs. patient controls			
		MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	D	-----	---------	----	------	--------	-------	-------	-------	------	---------	-------	-------	---------
	S	**87.2**	**99.9**	*0.2*	-63.5	**<0.0001**	100	99.3	97.8	97.2	**98.6**	*1.3*	-8.8	**<0.0001**
ARTEFACTS	D	**98.3**	**97.5**	*3.5*	0.2	**>0.1**	86.7	95	68.3	86.7	**84.2**	*11.3*	1.3	**>0.05**
	S	**100**	**99**	*1*	0.5	**>0.1**	86.7	99.2	68.4	90	**86**	*12.9*	1.1	**>0.1**

The ability to verify shared features of living things and man-made artefacts was then tested with the second statistical procedure. A Mann-Whitney test over items belonging to the two critical semantic domains was carried out on patient controls performance. The analysis showed that the patient control group had the opposite performance (Mann-Whitney $U_{(n.=62)}=13$; 2-tailed $p<0.0001$) with shared features of the two categories. This was due to an advantage with shared information related to living things in all patients but CAL. However, MU's performance was much more preserved in the case of shared features of artefacts ($\chi^2=12.2$, df=1, $p<0.0005$).

This result may suggest again that MU's ability to judge shared features was more impaired with living things than with artefacts, while the other patients showed the opposite behaviour with the two categories. Considering the data with respect to different statistical procedures, provides further robust evidence of the presence of a well established dissociation between living things and man-made artefacts in MU's performance. Firstly, he was significantly different with respect to the patient control group, when normality in the distribution of the patients' scores was assumed. Furthermore, he showed the classical dissociation when his performance was analysed singularly, while the behaviour of the patient controls group led the opposite effect of the critical variable to arise.

5.5.6.3 Knowledge of encyclopaedic information

The first statistical procedure was initially adopted to examine the data. MU's knowledge of encyclopaedic information (see table 51) about living things (48.6% correct) and man-made artefacts (75% correct) seemed to be highly defective when matched against normal subjects' performance (living things: $z=-11.7$; $p<0.0001$; man-made artefacts: $z=-14.3$; $p<0.0001$). When the same comparison was made with respect to patient controls, an impairment selectively affecting the living things class was found ($z=-4.5$; $p<0.0001$); in contrast no differences were observed between MU and patient controls with man-made artefacts.

Table 51: Semantic knowledge of encyclopaedic information for living things and man-made artefacts categories

Domain	%	**MU vs. normal controls**				%				**MU vs. patient controls**			
	MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	**48.6**	**98.6**	*1.2*	-11.7	**<0.0001**	89.7	93.1	75.3	94.7	**88.2**	*8.9*	-4.5	**<0.0001**
ARTEFACTS	75	**97.9**	*1.6*	-14.3	**<0.0001**	91.4	91.7	56.7	84.4	**81.1**	*16.6*	-0.4	**>0.1**

In the case of encyclopaedic information, the second statistical method was again used. The performance over items of the whole patient control group with the two semantic categories was examined, highlighting the presence of an effect in the opposite direction within patient controls (Mann-Whitney test over items: U=277; 2-tailed p<0.005). In fact, patient controls had better scores with living relative to man-made artefacts. However, MU's disadvantage with living things with respect to artefacts was again observed (χ^2=14.8, df=1, p<0.0005).

MU's behaviour was therefore different from that of the other HSE patients when asked to perform encyclopaedic judgements. Thus, MU's clear disadvantage related to living things was observed both when his performance was compared to that of the patient controls group, assuming the normality in the distribution of the patient controls scores, and when his individual behaviour was examined. However, patient controls showed a significant effect of the critical variable in the opposite direction, in favour of living things relative to artefacts, thus providing strong support to the dissociation across semantic categories observed in MU.

When the first statistical procedure was used, the knowledge MU had of shared and distinctive dimensions of encyclopaedic information was defective for both living things and man-made artefacts with respect to the mean percentage of normal subjects. In contrast, when the comparison between MU and patient controls was accomplished, MU's knowledge lacked as regard to both distinctive (z=-3; p<0.05) and shared (z=-7.2; p<0.0001) dimensions in the case of living things (see table 52). However, MU's knowledge of distinctive encyclopaedic features related to man-made artefacts was comparable to that shown by the patient control group.

Table 52: Semantic knowledge of encyclopaedic information: distinctive vs. shared features

Domain	Dist/shared	%	MU vs. normal controls				%				MU vs. patient controls			
		MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	**D**	**46.7**	**98.1**	*1.3*	-39.5	**<0.0001**	90.6	89.4	66.1	94.4	**85.1**	*12.9*	-3	**<0.005**
	S	**50.5**	**98.9**	*1.6*	-30.2	**<0.0001**	88.9	96.7	84.4	95	**91.2**	*5.6*	-7.2	**<0.0001**
ARTEFACTS	**D**	75	**97.9**	*1.6*	-14.3	**<0.0001**	91.4	91.7	56.7	84.4	**81.1**	*16.6*	-0.4	**>0.1**
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This finding was again proved through the use of the second statistical procedure. A Mann-Whitney test over items was performed in order to examine the ability of the group of patient controls in providing judgements about distinctive features of living things and artefacts. In this case, no significant differences were observed between patients in the two conditions (Mann-Whitney test over items: $U_{(n.=62)}=424$; 2-tailed $p>0.1$). However, when only MU's performance was taken into consideration, an advantage in judging distinctive features of artefacts relative to living things was found ($\chi^2=16.8$, df=1, $p<0.00005$), showing that his performance is sharply different from that of the patient controls.

Therefore, the examination of distinctive features only, provides very clear results: the assumption of the normality in the distribution of scores in the patient controls group highlights MU's deviant behaviour, selectively affecting the class of living things. Moreover, the analysis of MU's individual performance again corroborates the dissociation, while when the performance of the patient controls was examined separately, it did not show any effect of the critical variable. Therefore, also in the case of encyclopaedic information, at least as far as distinctive features are concerned, a very strong pattern of findings is observed, that of a damage to MU's living things knowledge relative to that associated to man-made artefacts.

5.5.6.4 Knowledge of functional attributes

Semantic knowledge of functional information was then examined through the adoption of the first statistical procedure. The comparison between MU's and normal subjects' performance with respect to the two semantic domains showed that the critical patient was widely impaired with both living things ($z= -38.5$; $p<0.0001$), where he scored 60% correct (slightly above chance), and artefacts ($z=-7.58$; $p<0.0001$), where MU was 94.6% correct. However, the comparison between patient controls and MU highlighted a selective deficit relative to the living things domain ($z=-8.44$; $p<0.0001$), but he did not significantly differ from patient controls in the case of man-made artefacts (see table 53).

Table 53: Semantic knowledge of functional information for living things and man-made artefacts categories

Domain	%	MU vs. normal controls				%				MU vs. patient controls			
	MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	**60**	**98.5**	*1*	-38.5	**<0.0001**	91.7	91.6	76.7	84.2	**86.1**	*6.3*	-8.44	**<0.0001**
ARTEFACTS	**94.6**	**99.3**	*0.6*	-7.58	**<0.0001**	100	97.9	74.6	95.8	**92.1**	*7.5*	0.33	**>0.1**

The performance of patient controls and MU was then analysed separately with respect to the categories of living things and man-made artefacts by using the second statistical procedure. The examination of MU's scores alone with respect to functional knowledge of the two categories (χ^2=34.1, df=1; p<0.00001) provides support to the dissociation observed when his performance was compared to that of the patient controls group, assuming the normality in the distribution of the patients group scores. However, when the performance of patient controls with the two semantic classes was analysed separately over items, a significant effect of the critical variable was observed (Mann-Whitney test over items: $U_{(n.=62)}$=289; 2-tailed p<0.01), and the effect was in the same direction as in patient MU.

Therefore in the case of functional knowledge, a general convergence of the expected pattern of findings is not found, probably due to an effect in the same direction with respect to MU in control patients' scores with the two domains. However, the difference is very marked in the first analysis (p<0.0001), so a qualitative difference in the standard deviation between MU and the patient controls seems to support the assumption. As it will be observed below in this section and in the conclusion to this experimental investigation (section 5.5.10), further investigation of this type of semantic information is needed to achieve a better understanding of the category-specific effect shown by patient MU.

It is however worth noting, as will be shown below in section 5.5.6.5, that MU's ability to judge functional information about living things (60% correct, slightly above chance) was much better than in the case of sensory properties (see table 55), where he was only 48.9% correct (below chance). When the two results were compared, a significant difference was found (χ^2=7.14, df=1; p<0.01). However, in patient MU the ratio between functional/sensory correct judgements for living things was 1.23, while in the case of man-made artefacts it was 1.13, showing therefore not an impressive difference with respect to both categories. An advantage in judging functional properties (94.6%, table 53) with respect to sensory features (83.3% correct, table 55) was also observed in the case of man-made artefacts, and the difference in MU's performance with the two types of attributes was statistically significant ($\chi^2 = 15.5$; df=1; $p<0.0001$). This result shows the same tendency observed as regards to the findings discussed in the attribute production task for living things and man-made artefacts (section 5.5.2.1). In that task a large difference was found in MU's production of functional attributes of living things (41% correct, table 35) with respect to sensory ones (16% correct), and the same trend was observed also in the case of the man-made artefacts category (functional: 42% correct vs. sensory: 17% correct).

By the use of the first statistical procedure, both distinctive and shared dimensions of functional information (see table 54) of living things were highly impaired in MU, irrespectively of whether his performance was contrasted to that of normal subjects (distinctive: $z=-38$; $p<0.0001$; shared: $z=-19.7$; $p<0.0001$) or that of patient controls (distinctive: -2.6; $p<0.005$; shared: $z=-4.3$; $p<0.0001$). As far as man-made artefacts were concerned, a deficit affecting the knowledge of the distinctive dimension of functional information was found only after the comparison between MU and normal subjects ($z=-10.2$; $p<0.0001$), while MU's performance with shared functional features was comparable to that of the normal control group. When patient controls were confronted to MU, no differences were reported in the case of both distinctive and shared functional information about man-made artefacts. However, his knowledge of shared functional properties of living things was significantly better than that related to distinctive ones ($\chi^2 = 18.7$; df=1; $p<0.0001$).

Table 54: Semantic knowledge of functional information: distinctive vs. shared features

Domain	**Dist/shared**	%	**MU vs. normal controls**				%				**MU vs. patient controls**			
		MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	**D**	**45**	**98.2**	*1.4*	-38	**<0.0001**	90	94.2	65.9	72.5	**80.6**	*13.6*	-2.6	**<0.005**
	S	**75**	**98.7**	*1.2*	-19.7	**<0.0001**	93.4	89.2	87.5	95.9	**91.5**	*3.8*	-4.3	**<0.0001**
ARTEFACTS	**D**	**93.3**	**99.4**	*0.6*	-10.2	**<0.0001**	100	97.2	75.5	94.4	**91.8**	*11.1*	0.1	**>0.1**
	S	**98.3**	**98.9**	*1.4*	-0.43	**>0.1**	100	100	71.7	100	**92.9**	*14.2*	0.4	**>0.1**

Using the second statistical procedure, when MU's knowledge was taken into consideration singularly, he was clearly defective with respect to patient controls both with distinctive ($\chi^2=54.7$, df=1, $p<0.00001$) and shared features (χ^2=23.5, df=1, p<0.00001) of living things. The performance of the HSE patients group with distinctive features of living things and man-made artefacts was then separately analysed over items, highlighting a significant difference among patients' performance (Mann-Whitney test over items: $U_{(n.=62)}$=141; 2-tailed p<0.001). This result showed that in this case also patient controls had a not uniform behaviour with respect to the two categories. It was not possible to perform the same procedure in the case of shared features, since the number of items of the two categories was unequal.

Therefore, in the case of distinctive functional attributes, convergent evidence comes from the analysis of MU's behaviour alone and with respect to patient controls, when the assumption of the normality in their scores distribution is made. However, also the patient control group shows an effect of the critical variable in the same direction as MU, making this result of less straightforward interpretation. Also in this case, however, the first statistical method highlights a large dissociation between living things and man-made artefacts knowledge of distinctive functional properties in the critical patient. The variability in the patient controls group with distinctive features of the two semantic categories might therefore account for the result. However, MU's knowledge of functional features of both living things and man-made artefacts needs therefore further examination, and some suggestions will be proposed later in this chapter (section 5.5.10).

5.5.6.5 Knowledge of sensory attributes

By the adoption of the first statistical procedure, MU's knowledge of sensory information of living things was severely affected when compared to the performance of both normal subjects (z=-55.4; p<0.0001) and patient controls (z=-14.6; p<0.0001). A deficit related to sensory properties of artefacts was instead observed in MU's performance only in comparison to normal subjects (z=-13.5; p<0.0001), but no difference was detected after the comparison of the critical patient with the mean performance of patient controls (see table 55). As observed in the previous section (5.5.6.4), MU's knowledge of sensory attributes of both living things (48.9% correct, where he was below chance level) and of man-made artefacts (83.3% correct) was poorer than in the case of functional properties (living: 60% vs. artefacts: 94.6%), and in both instances the difference was statistically significant. In MU's case, the ratio between functional and sensory features was 1.23 with living things and 1.13 with artefacts. The finding, as already outlined in section 5.5.6.4, mimics the general trend observed in the feature production task described in section 5.5.2, and will be discussed in the summary below (section 5.5.7) and in the general conclusion (section 5.5.10) of the present experimental investigation.

Table 55: Semantic knowledge of sensory information for living things and man-made artefacts categories

Domain	%	MU vs. normal controls				%				MU vs. patient controls			
	MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	48.9	**98.8**	*0.9*	-55.4	**<0.0001**	94.1	94.1	84.7	86.7	**89.9**	*2.8*	-14.6	**<0.0001**
ARTEFACTS	83.3	**97.6**	*1.06*	-13.5	**<0.0001**	94.1	90.4	67.1	90.8	**85.6**	*4.9*	-0.5	**>0.1**

Then, the examination of the group of patient controls with the second statistical procedure on the two conditions was performed through a Mann-Whitney test over items. It was shown that control patients did not show a significant effect of the critical variable (Mann-Whitney test over items: $U_{(n.=62)}=373$; 2-tailed $p>0.1$). However, MU's performance was again extremely defective in the case of living things with respect to man-made artefacts ($\chi^2=26.4$, df=1, $p<0.00001$), when considered separately from the patient controls group.

Therefore, different statistical procedures confirmed the pattern of results expected. On the one hand, MU's comparison with the patient controls group, assuming the normality in the distribution of the patient controls scores, and the examination of MU's individual performance with respect to the two semantic domains, highlighted a specific deficit affecting his knowledge of sensory attributes of living things relative to man-made artefacts. On the other hand, the separate analysis of the patient controls behaviour did not show a significant difference with respect to the two categories, strongly supporting the presence of a categorical dissociation in MU's knowledge of sensory properties.

The first statistical procedure was also used to examine MU's knowledge of distinctive and shared dimensions of sensory information (see table 56). Patient MU was impaired in the case of living things when he was compared both to normal subjects (distinctive: z=-47.6; p<0.0001; shared: z=-31.6; p<0.0001) and patient controls (distinctive: z=-7.6; p<0.0001; shared: z=-9.2; p<0.0001). However, though MU's knowledge of distinctive man-made artefacts was impaired when confronted to normal subjects' performance (z=-12.4; p<0.0001), the same was not found in the case of patient controls. MU's knowledge of shared features of man-made artefacts was instead comparable to that showed by normal subjects, and even significantly better than that of patient controls (z=+1.7; p<0.05).

Table 56: Semantic knowledge of sensory information: distinctive vs. shared features

Domain	**Dist/shared**	**%**	**MU vs. normal controls**				**%**				**MU vs. patient controls**			
		MU	Mean %	*sd*	z	p	BAI	CAL	MIO	SAR	Mean %	*sd*	z	p
LIVING	**D**	**36.7**	**98.6**	*1.3*	-47.6	**<0.0001**	94.4	95.5	82.8	83.3	**89**	*6.9*	-7.6	**<0.0001**
	S	**61.1**	**99**	*1.2*	-31.6	**<0.0001**	93.9	92.8	86.7	90	**90.8**	*3.2*	-9.2	**<0.0001**
ARTEFACTS	**D**	**77.8**	**97.6**	*1.6*	-12.4	**<0.0001**	94.4	91.7	63.3	90	**84.9**	*14.5*	-0.5	**>0.1**
	S	**100**	**97.6**	*2.3*	1.04	**>0.1**	93.3	86.7	78.3	93.3	**87.9**	*7.1*	1.7	**<0.05**

The second statistical method was then adopted to separately analyse the performance of MU and the patients group with distinctive features across the two category conditions. The same analysis related to shared features could not be carried out because of an unequal number of items in the two categories of living things and man-made artefacts. In the case of distinctive features, patients showed an equivalent behaviour with both categories (Mann-Whitney test over items: $U_{(n.=62)}$=402; 2-tailed p>0.1), while MU had the usual advantage for man-made artefacts both with distinctive (χ^2=34.5, df=1, p<0.00001) and shared features (χ^2=46.6, df=1, p<0.00001). This last finding may highlight that MU's deficit for living things involves both distinctive and shared features. Moreover, this result is clearly in contrast with Tyler et al.'s (in press) predictions that the knowledge of shared features should be more preserved than that of distinctive ones, particularly in the case of living things.

In conclusion, while the patient controls group, considered separately, shows no effect of the critical variable, MU's performance is clearly characterised by a dissociation favouring sensory knowledge of artefacts relative to living things, at least when distinctive features are taken into account. In addition, the assumption of normality in the scores distribution of patient controls, showed that MU's behaviour was deviant from that distribution; furthermore, a significant effect of the type of semantic domain was observed also when MU's performance was examined separately. These observations provide convincing evidence that MU's sensory knowledge deficit is well established and involves only the category of living things, leaving instead spared his knowledge of man-made artefacts.

5.5.6.6 Knowledge of semantic attributes of subcategories of living things and man-made artefacts

The performance of MU and the two control groups with respect to both subcategories of living things and subclasses of man-made artefacts was finally examined, and their behaviour with different semantic features was also taken into account. In the following cases, the first statistical procedure only was adopted, and the data related to the findings are presented in appendix A (tables from 13 to 17).

Looking at the general knowledge of HSE patients and normal subjects in this task, regardless the feature type dimension (see table 13, appendix A), a widespread deficit was observed in MU's performance when compared to normal subjects. However, a selective impairment limited to the three subcategories of living things, namely animals ($z=-5.6$; $p<0.0001$), birds ($z=-4.4$; $p<0.0001$), and fruits/vegetables ($z=-10.4$; $p<0.0001$) arose in MU's performance when the comparison was made with patient controls. In contrast, the three subclasses of man-made artefacts remained unaffected (see table 13, appendix A).

Category information knowledge relative to animals (98.3% correct), fruits/vegetables (90% correct) and birds (73.3% correct) was found to be disrupted in MU (see table 14, appendix A), both when his performance was compared to normal controls (animals: z= nc, p= indeterminate; birds: $z=-88.7$; $p<0.0001$; fruits/vegetables: $z=-19.8$; $p<0.0001$) and to patient controls (animals: $z=-2.9$; $p<0.005$; birds: $z=-5.2$; $p<0.0001$; fruits/vegetables: $z=-19.5$; $p<0.0001$). In contrast, MU's semantic knowledge of man-made artefacts subcategories was comparable to that of both normal subjects and patient controls.

Encyclopaedic knowledge related to different subcategories of living things and man-made artefacts was also investigated (see table 15, appendix A). MU was widely impaired with respect to normal subjects in all subcategories, but tools (MU: 98.3% correct), where he did not significantly differ from normal controls. However, the comparison of MU's performance to that of the patient control group showed a deficit limited to the three subcategories of living things (animals: z=-5; p<0.0001; birds: z=-2.6; p<0.005; fruits/vegetables: z=-6.4; p<0.0001), whereas no differences arose as far as subclasses of artefacts were concerned.

MU's knowledge of functional information associated to different subcategories (see table 16, appendix A) was found defective with respect to all subcategories but vehicles (MU's performance 100% correct), after comparison with normal subjects. When MU's performance was compared to that of patient controls, an impairment was present in the case of land animals (z=-3; p<0.05) and birds (z=-4.3; p<0.0001), while no differences were detected with respect to subcategories belonging to the man-made artefacts domain.

The first statistical procedure was finally used to evaluate the knowledge of sensory features of MU and the two control groups. MU was found to be affected in his knowledge of all the subclasses of living things and man-made artefacts if he was contrasted to the performance of normal subjects (table 17, appendix A). However, a deficit affecting exclusively the three subclasses of living things (animals: z=-10.9; p<0.0001; birds: z=-5.5; p<0.0001; fruits/vegetables: z=-6.6; p<0.0001), leaving instead spared the subcategories associated to man-made artefacts, was found after the comparison of MU's performance to that of patient controls (see table 17, appendix A).

5.5.6.7 Further analysis on the semantic attribute verification task

As can be observed by the examples of this task described in section 5.5.6, the answer modality characterising this task, based on yes/no responses (chance level: 50%), could lead to a large amount of variability due to chance responses. Therefore, an *A'* analysis was carried out on HSE patients' performance over the whole item set. This treatment, based on a modification of the signal detection model, is usually applied in order to determine which pairs of *discrimination (hit)* and *bias (false alarm)* responses show independence from answers due to wrong discriminations and abnormal bias (Snodgrass and Corwin, 1988). The choice to use *A'* discrimination index, which proposes, as an alternative measure of discrimination, the area under an isomemory curve, follows from the demonstration that this area is a good estimate of two-alternatives forced choice memory performance (Green and Moses, 1966), as was the case in this task. Each patient's correct (hit) and wrong (false alarm) "yes" responses underwent two different types of computations proposed by Grier (1971), provided that:

- if pairs of hit (H)/false alarm (FA) satisfy the condition of $H \geq FA$ the *A*' discrimination index is computed as follows:

$$A' = 0.5 + [(H-FA)(1+H-FA)]/[4H(1-FA)]$$

- if pairs of hit (H)/false alarm (FA) satisfy the condition of $FA > H$ the *A*' discrimination index is computed as follows:

$$A' = 0.5 - [(FA-H)(1+FA-H)]/[4FA(1-H)]$$

Table 57: Patients' data in the feature verification task for living things following *A*' computation

Information	Subclass	Shared/distinctive	Patient controls				MU vs. patient controls				
			Bai	Cal	Mio	Sar	Mean %	*sd*	MU	z	p
Category	Animals	S	1	1	1	1	**1**	*0*	**1**	nc	**indet.**
Encyclopaedic	Animals	D	1	1	0.8	0.9	**0.9**	*0.1*	**0.4**	-5.7	**<0.0001**
Encyclopaedic	Animals	S	1	1	0.9	1	**1**	*0*	**0.7**	-11.4	**<0.0001**
Functional	Animals	D	1	1	0.7	0.9	**0.9**	*0.1*	**0.4**	-3.9	**<0.0001**
Functional	Animals	S	1	1	1	1	**1**	*0*	**0.9**	-4.5	**<0.0001**
Sensory	Animals	D	1	1	0.7	0.9	**0.9**	*0.1*	**0.3**	-4.6	**<0.0001**
Sensory	Animals	S	1	1	1	1	**1**	*0*	**0.9**	-12.8	**<0.0001**
Category	Birds	S	1	1	1	1	**1**	*0*	**0.8**	-6.6	**<0.0001**
Encyclopaedic	Birds	D	0.9	1	0.6	1	**0.9**	*0.2*	**0.4**	-2.7	**<0.005**
Encyclopaedic	Birds	S	0.9	1	0.9	1	**1**	*0*	**0.8**	-3.3	**<0.001**
Functional	Birds	D	0.9	1	0.8	0.8	**0.9**	*0.1*	**0.4**	-5.7	**<0.0001**
Functional	Birds	S	0.9	0.8	0.8	0.9	**0.9**	*0*	**0.7**	-4.1	**<0.0001**
Sensory	Birds	D	0.9	1	0.9	0.9	**0.9**	*0*	**0.2**	-17.2	**<0.0001**
Sensory	Birds	S	0.9	0.9	0.8	1	**0.9**	*0.1*	**0.9**	-0.5	**>0.1**
Category	Fruits/Veg.	S	1	1	1	1	**1**	*0*	**0.9**	nc	**indet.**
Encyclopaedic	Fruits/Veg.	D	0.9	0.9	0.8	1	**0.9**	*0.1*	**0.4**	-6.6	**<0.0001**
Encyclopaedic	Fruits/Veg.	S	1	1	1	1	**1**	*0*	**0.8**	-9.3	**<0.0001**
Sensory	Fruits/Veg.	D	1	1	0.9	0.9	**0.9**	*0.1*	**0.4**	-9.7	**<0.0001**
Sensory	Fruits/Veg.	S	1	0.9	0.9	0.9	**0.9**	*0*	**0.3**	-18.9	**<0.0001**

nc= z score not computable

Table 58: Patients' data in the feature verification task for man-made artefacts following *A*' computation

Information	**Subclass**	**Shared/distinctive**	**Patient controls**				**MU vs. patient controls**				
			Bai	**Cal**	**Mio**	**Sar**	**Mean %**	***sd***	**MU**	z	p
Category	Household	**D**	0.9	1	0.8	0.9	**0.9**	*0.1*	**1**	1	**>0.1**
Encyclopaedic	Household	**D**	0.9	0.9	0.7	0.8	**0.8**	*0.1*	**0.8**	-0.6	**>0.1**
Functional	Household	**D**	1	1	0.9	1	**1**	*0*	**1**	-0.1	**>0.1**
Sensory	Household	**D**	1	0.9	0.7	0.9	**0.9**	*0.1*	**0.8**	-0.4	**>0.1**
Category	Utensils	S	1	1	1	0.9	**1**	*0*	**1**	0.9	**>0.1**
Encyclopaedic	Utensils	**D**	1	1	0.5	1	**0.9**	*0.2*	**1**	0.5	**>0.1**
Functional	Utensils	**D**	1	1	0.6	1	**0.9**	*0.2*	**0.9**	0.2	**>0.1**
Functional	Utensils	S	1	1	0.6	1	**0.9**	*0.2*	**1**	0.4	**>0.1**
Sensory	Utensils	**D**	1	1	0.6	1	**0.9**	*0.2*	**0.8**	-0.3	**>0.1**
Category	Vehicles	S	0.9	1	0.4-	1	**0.8**	*0.3*	**1**	0.6	**>0.1**
Encyclopaedic	Vehicles	**D**	1	1	0.6	0.9	**0.9**	*0.2*	**0.6**	-1.2	**>0.1**
Functional	Vehicles	**D**	1	1	0.9	1	**1**	*0*	**1**	0.8	**>0.1**
Sensory	Vehicles	**D**	1	1	0.9	0.9	**0.9**	*0.1*	**0.9**	-0.3	**>0.1**
Sensory	Vehicles	S	0.9	1	0.8	0.9	**0.9**	*0.1*	**1**	1.3	**>0.05**

As shown in tables 57 and 58, the correction of patients' data through the *A*' analysis did not lead to different conclusions with respect to those examined in detail in this experimental section through the use of the first statistical method. The expectation of a cross-categorical effect reflecting the differential weight of semantic information type (sensory information in the living things case and functional properties as respect to artefacts) was therefore not supported by the results of this task.

5.5.7 Summary

A wide array of findings resulted from the feature verification task about living things and man-made artefacts. Actually, different levels of analysis can be performed on the data obtained from this experiment: (i) a categorical distinction over the semantic domains of living things and man-made artefacts; (ii) a cross-categorical confrontation between different types of semantic properties (category, encyclopaedic, functional and sensory information); (iii) an examination along the semantic dimension of distinctiveness/sharedness; (iv) finally, a comparison in terms of semantic subclasses (land animals, birds and fruits/vegetables vs. household items, tools and vehicles) can be performed. MU's performance in this task was confronted to that of two control groups: normal subjects (using the first statistical procedure only) and patient controls (using both the first and second statistical treatments).

The comparison of MU's performance to that of normal subjects does not lead to the emergence of highly relevant effects. In general, the critical patient is severely defective as regards to both semantic domains of living things and man-made artefacts when his scores are confronted to the mean percentage performance of normal controls (table 47). A generalised impairment is also shown to affect all the considered subclasses (table 13, appendix A). In the evaluation of MU's featural knowledge, he was comparable to the normal subject group only (a) in the case of category information about the main domain and related subcategories of artefacts (table 49; table 14, appendix A); (b) both with distinctive and shared information of man-made artefacts (table 50); (c) encyclopaedic information about tools (table 15, appendix A); (d) functional knowledge of vehicles (table 16, appendix A); (e) shared functional properties of artefacts (table 54); (f) finally, shared sensory information about artefacts (table 56). These results, as pointed out in the methodological section (5.2), highlight the limitations intrinsic to a methodology which restricts the comparison of a patient's performance to that of normal subjects. From the above considerations, it follows the importance of using the mean performance of patient controls in comparison to that shown by a single critical patient, provided that both have suffered from the same aetiology. As matter of facts, normal subjects usually performed at ceiling in this task, thus offering no ground for a fine-grained evaluation of the patient's deficit, with a loss of precious information about patient's relatively preserved skills. However, this is less likely to happen if a patient control group is adopted.

In effect, the comparison of MU's performance with that of patient controls, leads a dissociation between two domains of knowledge to emerge, highlighting a selective deficit involving MU's semantics of the living things class (table 47). Moreover, patient's categorical impairment consistently affects all three subclasses belonging to the living things domain (table 13, appendix A), while household items, tools and vehicles remain virtually spared.

Far more interesting for the purposes of the present experiment, are the data obtained through the evaluation of MU's featural knowledge: as described above, MU's ability to verify the appropriateness of different types of statement about the general domain of man-made artefacts and their subclasses was intact (table 47). In contrast, a general featural deficit, massively affecting the domain of living things and each of the related subclasses, is found (table 47). Remarkably, various sources of semantic information, such as category, encyclopaedic, functional and sensory information, do not differentially affect patient's performance as respect to both the living things and man-made artefacts classes. The knowledge of living things and all associated subcategories is found to be impaired relative to the man-made artefacts class as regard to (i) category information (table 49 and table 14, appendix A); (ii) encyclopaedic information (table 51 and table 15, appendix A); (iii) functional properties (table 53 and table 16, appendix A); (iv) sensory features (table 55 and table 17, appendix A). Therefore, no interaction between semantic class and attribute type is found in this experimental task.

Finally, the assessment of MU's knowledge along the distinctiveness/sharedness dimension does not reveal the presence of dissociations differentially affecting the domain of living things, as both shared and distinctive semantic information are equally impaired (table 48). Similarly, in the case of the main class of man-made artefacts no differences arise between distinctive and shared types of information, being MU's and patient controls' performance closely comparable (table 48). A lack of dissociation between distinctive and shared information of living things and man-made artefacts is found even with respect to the four types of semantic properties, being living things always affected and man-made artefacts always spared, regardless the distinctive-shared semantic dimension. The only exception is the significantly better performance of MU with shared information related to sensory knowledge of man-made artefacts (table 56), a finding that is not predicted by Tyler and co-workers (1997; in press), as discussed in section 3.3.3.

However, assuming a single case perspective, and examining the performance of patient MU only, the strikingly difference between his knowledge of functional vs. sensory information, found through the attribute generation tasks described before, is present, although in a mild form, since sensory information about living things are generally defective (see figure 15). Moreover, when MU's performance in judging sensory and functional information about both living things and man-made artefacts is examined, a decrease is found in the case of sensory properties relative to functional ones (compare tables 53 and 56), with a statistically significant difference of about 10% in favour of functional attributes for both semantic domains.

Even though a category specific deficit relative to living things is again confirmed by the findings of this task, the expected difference between MU's ability to judge functional and sensory types of semantic information is only found in a mild way, and a pure categorical effect, favouring man-made artefacts emerges from these findings.

5.5.8 Feature verification task about "mass" categories

A feature verification task aimed at probing the categorical and featural knowledge associated to different "mass" kinds in patient MU, was devised, as described in the introduction to this experimental section (5.5.1), from a featural database of semantic information about the "mass" category. The procedure followed for the realisation of this database (see appendix D) was based on the same rationale adopted by Garrard et al. (unpublished) in the collection of their database of featural knowledge about living entities and man-made artefacts stimuli.

Therefore, 10 normal Italian subjects, all graduated students, were asked to provide semantic properties related to three main categories of "mass" items: the experimental subjects were required to list on a written form the largest number of information they considered to exhaustively describe each of 118 stimuli, *a priori* subdivided as follows: 52 edible substances, 27 liquids and 39 materials. Following the same procedure used by Garrard and colleagues, subjects were driven to provide information about four different sources of semantic knowledge: the category to which an item belongs, encyclopaedic information, functional, and sensory attributes. From this larger set of semantic features, a reduced featural database, comprising semantic information related to the item set of 40 stimuli adopted in the basic battery for the assessment of semantic knowledge related to "mass" kinds (section 5.4.4), was selected. Each main category further comprised subclasses of stimuli. Edible substances (16 items) could be furthermore subdivided into 8 sauces (4 powdery and 4 creamy sauces) and 8 foods (4 meats and 4 cheeses); 8 liquids were classified as being alcoholic drinks (4 items) and non alcoholic drinks (4 items); finally, the broad and mostly undefined category of 16 materials was partitioned into the following sets: 4 metals and 4 precious stones on the one hand (8 items), 4 textiles and 4 "other kinds of materials" on the other (8 items).

The entire set of semantic properties given by the group of 10 normal subjects was then examined and adapted following Garrard and co-workers' criteria: 1) responses were divided into individual components of information, e.g.: "wine is red or white" was recorded as "wine is red" and "wine is white"; 2) composite attributes which contained separate pieces of information, e.g. "champagne is drunken into special types of glasses" were coded as "champagne is drunken" and "champagne is drunken into special types of glasses"; 3) responses that were identical or had similar meanings were grouped together, e.g.: "wood is resistant", "wood is compact". In a second stage, a standardised wording was assigned to attributes across the entire stimulus set (e.g.: "porcelain can be broken", "glass is easy to crash" were all recorded as instances of "is fragile"). As a general procedure, all the properties provided by subjects were preserved in the database, with the exception of the following cases: 1) "can" responses, indicating attributes that may or may not be true (e.g.: "grappa can be transparent") were changed as "is" attributes; 2) responses that identified subordinate instances of the item (e.g.: "gorgonzola cheese is Gin" or "plastics is ABS") were excluded; 3) qualifying expressions such as "diamond is quite resistant" were rephrased as "diamond is resistant"; 4) responses that were highly idiosyncratic or difficult to classify, such as "emmenthal cheese is an unpleasant type of cheese" or "a diamond is something everyone wants", were omitted. Finally, each property was designated as an instance of categorical, encyclopaedic, functional and sensory information, according to the criteria described in section 5.5.1. Therefore, "gold is a metal" was classified as a categorical information; "gold is expensive" was designated as an instance of encyclopaedic information; "gold can be warmed" was ascribed to the set of functional properties; "gold is yellow" was categorised as a sensory attribute.

From the 40 items featural database, two indexes of semantic relatedness to the three main categories were computed with the same procedure followed by Garrard and colleagues: <u>dominance</u> (the proportion of subjects who generated the attribute) and <u>distinctiveness</u> (the extent to which a feature allows a particular concept to be distinguished from other members of the same category). In devising this feature verification task, a subset of features related to the 40 items was selected, provided that the means and standard deviations of the distinctiveness index were as far as possible comparable according to: (i) each of the three semantic domains; (ii) subcategories within a domain; (iii) semantic information types (see table 59: sd are in parentheses). However, the data regarding the feature verification task about "mass" kinds will not comprise the sharedness/distinctiveness dimension of semantic features: this relevant control will be performed in a subsequent time, through the use of a higher number of subjects (at least 20), when MU's performance shall be reassessed over a much wider set of items.

Table 59: Mean and standard deviation *(in parentheses)* of semantic features with respect to the sharedness/distinctiveness continuum

	Shared/distinctiveness	Category	Encyclopaedic	Functional	Sensory
WHOLE SET	**S.**	0.68 *(0.05)*	0.70 *(0.17)*	0.57 *(0.08)*	0.56 *(0.06)*
	D.	0.28 *(0.09)*	0.14 *(0.11)*	0.14 *(0.09)*	0.16 *(0.1)*
SUBSTANCES	**S.**	0.73 *(0.01)*	-------------	-------------	-------------
	D.	0.32 *(0)*	0.14 *(0.11)*	0.14 *(0.1)*	0.13 *(0.08)*
LIQUIDS	**S.**	0.65 *(0)*	0.84 *(0.08)*	0.55 *(0.1)*	0.67 *(0.03)*
	D.	0.21 *(0.08)*	0.13 *(0.1)*	0.16 *(0.07)*	0.22 *(0.12)*
MATERIALS	**S.**	0.63 *(0.01)*	0.53 *(0.05)*	0.6 *(0)*	0.52 *(0.01)*
	D.	0.3 *(0.1)*	0.14 *(0.12)*	0.14 *(0.09)*	0.17 *(0.11)*
Foods	**S.**	0.74 *(0)*	-------------	-------------	-------------
	D.	-------------	0.14 *(0.11)*	0.16 *(0.11)*	0.13 *(0.08)*
Sauces	**S.**	0.72 *(0)*	-------------	-------------	-------------
	D.	0.32 *(0)*	0.14 *(0.11)*	0.12 *(0.08)*	0.12 *(0.07)*
Alcoholic drinks	**S.**	0.65 *(0)*	0.81 *(0.09)*	0.59 *(0.11)*	-------------
	D.	0.16 *(0.12)*	0.15 *(0.09)*	0.15 *(0.07)*	0.24 *(0.12)*
Non alcoholic drinks	**S.**	0.65 *(0)*	0.9 *(0)*	0.47 *(0)*	0.67 *(0.03)*
	D.	0.25 *(0)*	0.12 *(0.1)*	0.16 *(0.08)*	0.20 *(0.12)*
Metals and precious stones	**S.**	0.64 *(0)*	0.53 *(0.05)*	0.6 *(0)*	0.52 *(0.17)*
	D.	0.33 *(0.07)*	0.14 *(0.12)*	0.13 *(0.07)*	0.17 *(0.08)*
Textiles and other materials	**S.**	0.62 *(0)*	-------------	-------------	-------------
	D.	0.24 *(0.14)*	0.14 *(0.11)*	0.14 *(0.1)*	0.18 *(0.13)*

The selected set of semantic features was then fitted into singular yes/no questions. As already done in the previous feature verification task (section 5.5.6), in order to ensure the same probability to answer with a yes or a no, each item-feature pair was coupled with a different feature which was plausible, but did <u>not</u> pertained to the item, provided that the latter feature had a comparable level of distinctiveness (e.g.: category: "is mayonnaise a sauce?/is mayonnaise a material?"; encyclopaedic: "is mineral water added with gas?/is mineral water found in jewellery?"; functional: "can wood be cut?/can wood be eaten?"; sensory: "is coarse salt white?/is coarse salt reddish?"). Table 60 provides the number and distribution of questions over (i) the three general classes of "mass" stimuli and (ii) the different types of semantic information. In a separate section (5.5.8.6), MU's and the normal controls behaviour will be discussed as regard to their knowledge of subcategories of substances, liquids and materials, and the related data will be presented from table 18 to 22 in appendix A.

Table 60: Number of questions for the three semantic classes and related subcategories, and for each type of semantic information

	Category	Encyclopaedic	Functional	Sensory
WHOLE SET	102	840	704	582
SUBSTANCES	32	384	268	234
LIQUIDS	20	204	118	100
MATERIALS	50	252	318	248
Foods	16	212	136	122
Sauces	16	172	132	112
Alcoholic drinks	12	94	64	50
Non alcoholic drinks	8	110	54	50
Metals and precious stones	28	134	132	124
Textiles and other materials	22	118	186	124

The feature verification task was administered both to patient MU and a group of 5 normal subjects, matched to patient MU, according to sex, age and years of schooling (see table 61).

Table 61: Description of 5 normal subjects used as controls to patient MU

N. of subjects	Sex	Education	Age Mean and range
5	M	13	30.2 range 28-33

The featural questionnaire was then orally presented to MU and the 5 normal subjects in a random sequence. A notably high number of trials (2228 questions) characterised this task, where 918 questions regarded substances, 442 were about liquids, and 868 were related to materials knowledge. The questionnaire was presented to MU in about 10 sessions, each of them lasting about 1 hour, with a week of distance between sessions, in order to prevent patient's fatigue and an increasing rate of stereotyped answers. Patient MU could stop about six times within each testing session, whenever he needed it. Normal subjects could instead conclude the task in about 4 sessions; in their case, each test session lasted about 2 hours, and normal subjects were allowed to take any break they needed. The analysis of the data was performed using only the first statistical procedure (section 5.2), and therefore assuming the normality in the distribution of normal controls and comparing MU to the mean of normal subjects' performance by the use of Z scores. Tables from 62 to 66 present: (i) the percent of correct answers given by patient MU; (ii) the mean percentage and standard deviation of correct answers provided by the group of normal subjects; (iii) z scores and related levels of significance which allowed a direct comparison of MU's performance to that of the normal controls group.

5.5.8.1 General knowledge of substances, liquids and materials

In general, MU demonstrated to have a semantic knowledge of the "mass" domain largely disrupted in comparison to the performance of the group of normal subjects (see table 62). In fact, following the first statistical procedure, he was significantly different from the control group on all the three categories of substances ($z=-6.14$; $p<0.0001$), liquids ($z=-8.89$; $p<0.0001$) and materials ($z=-8.29$; $p<0.0001$).

Table 62: Semantic knowledge of substances, liquids, and materials categories

Domain	%	MU vs. normal controls			
	MU	Mean %	*sd*	z	p
WHOLE SET	53	92.3	*5.3*	-7.4	<0.0001
SUBSTANCES	53.1	91.8	*6.3*	-6.14	<0.0001
LIQUIDS	54.7	93.8	*4.4*	-8.89	<0.0001
MATERIALS	52.1	91.9	*4.8*	-8.29	<0.0001

5.5.8.2 Knowledge of category information

As in the previous feature verification task (5.5.6), the examination of patient's knowledge of semantic properties of substances, liquids, and materials categories was then accomplished.

Normality in the distribution of the scores of normal controls was assumed, and MU's performance was compared to that of the control group. MU's knowledge of category information was impaired in comparison to normal subjects (see table 63) as regards to all the three categories of substances ($z=-1.82$; $p<0.05$), liquids ($z=-4$;

p<0.0001) and materials (z=-5.04; p<0.0001).

Table 63: Semantic knowledge of category information for substances, liquids, and materials categories

Domain	%	MU vs. normal controls			
	MU	Mean %	*sd*	z	p
WHOLE SET	60.8	94.1	*5.9*	-5.64	<0.0001
SUBSTANCES	87.5	97.5	*5.5*	-1.82	<0.05
LIQUIDS	80.0	98	*4.5*	-4	<0.0001
MATERIALS	36.0	90.4	*10.8*	-5.04	<0.0001

5.5.8.3 Knowledge of encyclopaedic information

By the use of the first statistical procedure, MU's knowledge of encyclopaedic information in contrast to normal subjects (see table 64) was found to be thoroughly affected as regards to all the substances (z=-3.51; p<0.0005), liquids (z=-12.7; p<0.0001) and materials (z=-7.6; p<0.0001) classes.

Table 64: Semantic knowledge of encyclopaedic information for substances, liquids, and materials categories

Domain	%	MU vs. normal controls			
	MU	Mean %	*sd*	z	p
WHOLE SET	56.4	91.8	*4.3*	-8.23	<0.0001
SUBSTANCES	54.7	91.6	*10.5*	-3.51	<0.0005
LIQUIDS	59.8	94.1	*2.7*	-12.7	<0.0001
MATERIALS	56.3	90.5	*4.5*	-7.6	<0.0001

5.5.8.4 Knowledge of functional attributes

The critical patient's and the normal control group's performances with respect to their knowledge of functional properties of "mass" kinds were examined through the adoption of the first statistical procedure. MU's ability to deal with functional information about the three domains was therefore examined as opposed to that shown by normal subjects. The patient (see table 65) was again extremely defective as respect to all substances (z=-3.12; p<0.001), liquids (z=-5.14; p<0.0001) and materials (z=-9; p<0.0001).

Table 65: Semantic knowledge of functional information for substances, liquids, and materials categories

Domain	%	MU vs. normal controls			
	MU	Mean %	*sd*	z	p
WHOLE SET	**66.2**	**93.5**	*5.2*	-5.25	**<0.0001**
SUBSTANCES	**67.9**	**91.6**	*7.6*	-3.12	**<0.001**
LIQUIDS	**64.4**	**93.2**	*5.6*	-5.14	**<0.0001**
MATERIALS	**65.4**	**95.1**	*3.3*	-9	**<0.0001**

However, it should be observed that MU's ability to verify questions about functional properties (table 65) of "mass" stimuli was at least twice as better (66.2% correct over the whole set) than in the case of sensory (table 66) attributes (30.9% correct over the whole item set). Normal subjects, in contrast, showed a comparable performance with both types (see tables 65 and 66) of semantic information (functional: 93.5% correct; sensory: 91.1% correct) over the whole set of items.

5.5.8.5 Knowledge of sensory attributes

Using the first statistical procedure, it was observed that MU's knowledge of sensory properties associated to the three main domains (see table 66) was, similarly to the findings previously described in this experimental section (5.5.8), massively affected when compared to the performance of normal subjects, both with substances (z=-6.78; p<0.0001), liquids (-8.59; p<0.0001) and materials (z=-8.22; p<0.0001) categories.

Table 66: Semantic knowledge of sensory information for substances, liquids, and materials categories

Domain	%	MU vs. normal controls			
	MU	Mean %	*sd*	z	p
WHOLE SET	30.9	91.1	*7.2*	-8.36	<0.0001
SUBSTANCES	29	91.4	*9.2*	-6.78	<0.0001
LIQUIDS	28	93.2	*7.6*	-8.59	<0.0001
MATERIALS	33.9	89.8	*6.8*	-8.22	<0.0001

As already observed in section 5.5.8.4, MU's knowledge of sensory properties of the "mass" category was extremely poor. In fact, he was about 30% correct overall (below chance level) in the case of all three categories of substances (29% correct), liquids (28% correct) and materials (33.9% correct). However, MU's scores related to functional information were much higher, with a mean performance of 66.2% correct over the whole item set. Analysing the ratio between functional and sensory attributes correctly judged by MU over the different classes of "mass" stimuli, it can be shown that an advantage for functional features with respect to sensory ones is always observed (whole set: ratio functional/sensory: 2.14; substances: ratio functional/sensory: 2.34; liquids: ratio functional/sensory: 2.3; materials: ratio functional/sensory: 1.93).

When MU's performance with respect to functional and sensory features of the three classes belonging to the "mass" category was covariated with the performance of normal controls, a main effect of Feature was observed (F=102.3; df=1; p<0.0001), whereas the main effect of Category (F=0.93; df=2; p>0.1) and the Feature×Category interaction were found to be non significant. Moreover, normal controls' performance, which was covariated to MU's scores, did not lead to a statistically significant result (F=1.5; df=1; p>0.1).

5.5.8.6 Knowledge of semantic attributes of subcategories of "mass" kinds

By the use of the first statistical procedure, MU's semantic knowledge of stimuli belonging to subcategories of the three main domains was then examined in comparison to the mean performance of the normal control group. MU's and normal subjects' performance with respect to their knowledge of different semantic features was also taken into account and tested.

His performance as regards to six subcategories of substances, liquids and materials (see table 18, appendix A) was therefore taken into consideration. His scores were always poorer that those given by normal controls. MU's knowledge of subcategories of the general "mass" domain was severely defective with respect to normal controls in all of the cases.

The patient's performance related to category information about subcategories of substances, liquids and materials was also analysed (see table 19, appendix A). The categorical knowledge of all subclasses was shown to be disrupted in patient MU when confronted with the mean performance of normal subjects. However, he demonstrated to be equal to the normal control group in the case of foods categorical knowledge (100% correct).

MU's performance regarding encyclopaedic features associated to subcategories of substances, liquids and materials was then examined (see table 20, appendix A). As already observed in the preceding cases, the patient showed an impaired performance over all subcategories.

A further analysis of MU's performance with respect to subcategories of substances, liquids and materials (see table 21, appendix A) put in evidence MU's general impairment over all subclasses in comparison to the mean performance of the control group.

On the lines with the above results, MU was affected in his sensory knowledge of all the subclasses of substances, liquids and materials in comparison to normal subjects (see table 22, appendix A), showing a severe and widespread impairment.

5.5.9 Summary

The feature verification task about substances, liquids and materials categories allowed an ameliorate and much comprehensive account of MU's semantic competence as respect to three classes of "mass" kinds. As shown by the findings described in this section (5.5.8), this task seems to be much more sensitive than the questionnaire about "mass" items presented in section 5.3.1.3. As in the previous feature verification task (section 5.5.6), carried out with respect to living things and man-made artefacts knowledge, multiple level analyses of the present findings could be performed as regards to: (i) a categorical confrontation over the semantic classes of substances, liquids and materials; (ii) a cross-categorical segregation over different types of conceptual knowledge (category, encyclopaedic, functional and sensory information); (iii) a comparison among semantic subcategories (foods/sauces; alcoholic drinks/non alcoholic drinks; metals and precious stones/textiles and "other materials"). In this task, MU's semantic competence was matched to that of a control group of 5 normal subjects of his sex, age and education by the use of the first statistical procedure.

On the whole, patient MU showed an highly impaired performance in comparison to that of the control group as far as substances, liquids and materials classes are concerned (table 62). His ability to verify the appropriateness of semantic properties as regards to subclasses of the three main domains is found to be thoroughly defective as respect to the mean performance of normal controls (table 18, appendix A).

Remarkably, the findings obtained when MU's featural knowledge was evaluated, provide useful information with respect to the semantic processes which might underlie the conceptual knowledge of different kinds of "mass" items. MU's knowledge of the three domains (tables from 63 to 67) and associated subcategories (tables 18 to 22, appendix A), is completely disrupted with respect to the mean performance of normal subjects as far as the four types of semantic information are taken into consideration, with the only exception of MU's categorical knowledge of foods (table 19, appendix A) that are found to be spared.

However, if one considers the performance of the single patient MU, his ability to verify the appropriateness of functional features about "mass" stimuli is much more preserved than is the case of sensory properties (figure 16). The pattern of results observed in the feature verification task about "mass" kinds, therefore, mimics the findings related to living things obtained in the previous feature verification task described in section 5.5.6. With living things, MU showed a generalised impairment over the four different information types, in contrast with a performance comparable to that of patient controls with man-made artefacts. However, also in that case (sections 5.5.6.4 and 5.5.6.5), a significant difference was found in his ability to deal with the two types of semantic information, with a clear advantage in the case of functional vs. sensory attributes both in the case of living things and man-made artefacts. Therefore, the two feature verification tasks provide fundamental information about MU's knowledge of functional (better preserved) and sensory features (severely defective) about three different semantic domains, living things, man-made artefacts and "mass" kinds, and give further support to the findings obtained through the two attribute generation tasks discussed in sections 5.5.2 and 5.5.4.

Therefore, as will be extensively discussed in the general conclusion (5.5.10) of this experimental section, the present findings are in keeping with both the results obtained from two attribute generation tasks (5.5.2 and 5.5.4), and with the previous feature verification task about living things and man-made artefacts (5.5.6).

The fact that such an impairment, severely affecting in a cross-domain fashion sensory knowledge of all the "mass" classes, in contrast to a better performance as respect to functional attributes knowledge, when looked from a single case perspective, is however concealed by MU's comparison to the almost perfect performance of normal subjects, stresses again, from a methodological point of view, the importance of using patients as controls to MU's performance (see section 5.2).

5.5.10 General conclusion

The fundamental relevance of an assessment of semantic attribute knowledge in patients with a category specific deficit for living things, man-made artefacts and "mass" classes (see table 67) was addressed through the administration of two tasks, the first assessing the spontaneous production of semantic properties (sections 5.5.2 and 5.5.4), and the second characterised by a feature verification paradigm (5.5.6 and 5.5.8).

Attribute production tasks

When MU' production of semantic properties is examined, a quite consistent pattern of deficits and preservations is observed in MU's ability to provide different types of semantic information, in particular functional and sensory attributes. Some variability is instead observed as far as the production of category and encyclopaedic information is considered.

In the attribute generation task related to living things and man-made artefacts (section 5.5.2), an advantage in favour of the relative sparing of functional information is found in MU's performance, irrespectively to different domains and subdomains. MU's general ability to spontaneously produce more functional attributes than sensory features is again observed for "mass" kinds (section 5.5.4). In the case of the broad class of "mass", MU's difficulty (see figure 17) regarding the generation of sensory features (15.1% correct, table 40, section 5.5.4.1) is consistent to his performance with living things (15.7% correct, table 35, section 5.5.2.1). A comparable level of performance is also observed in MU's production of functional features of "mass" (37% correct, table 40, section 5.5.4.1) and living things (40.7% correct, table 35, section 5.5.2.1). However, his production of semantic features is not comparable in the case of category (5% vs. 16.7% correct respectively) and encyclopaedic (42.9% vs. 26.8% correct respectively) information about "mass" and living things. As far as man-made artefacts are concerned, a performance similar to that found with respect to the other four categories, living things, substances, liquids and materials, is observed. In particular, MU's ability to produce semantic information about functional and sensory attributes of man-made artefacts (see figure 17) presents the same pattern described for living things and three types of "mass" stimuli, with functional properties (42.1% correct, table 36, section 5.5.2.1) being retrieved twice as better than sensory features (17.3% correct, table 36, section 5.5.2.1).

Even though a direct comparison of MU's performance to that of patient controls cannot be performed for both attribute generation tasks, since the patient control group only participated to the first task (5.5.2), but not to that about "mass" kinds knowledge (5.5.4), it might be nonetheless worth to examine semantic attribute production as respect to living things, man-made artefacts, and the three classes of "mass" kinds. Therefore, MU's vs. patient controls' performance as respect to the living things and man-made artefacts task on the one hand, and, secondly, MU's performance vs. the mean scores of a group of ten normal subjects on the task involving "mass" kinds will be compared.

The overall performance of patient MU and that of the two groups of controls is generally comparable (and even better than patient controls in the case of living things (table 35, section 5.5.2.1) and substances (table 41, section 5.5.4.2) as far as functional information is concerned. However, and most importantly (see figure 18), MU's disadvantage in the case of sensory properties production with respect to the whole array of semantic categories is clearly highlighted, both in comparison to patient (section 5.5.2) and normal controls (section 5.5.4).

A substantial support is provided by these findings to the likelihood of a close relation between living things and a new sensory-quality category, that of "mass", as observed in the first experimental section (5.3), and, secondly, when MU's categorical knowledge related to the same semantic domains was assessed through two batteries of tasks (sections 5.4.2 and 5.4.4). Actually, the results described in sections 5.5.2 and 5.5.4 offer a more wide-ranging picture of MU's semantic memory impairment: his deficit is not only limited to the broad categorical knowledge of living things and "mass" kinds, in contrast to a spared semantics in the case of man-made artefacts, as observed in the preceding parts of this study (sections 5.3 and 5.4). MU's impairment (sections 5.5.2 and 5.5.4), in fact, extensively involves also his featural knowledge of sensory attributes, whereas functional information remains unimpaired in all three domains of living things, man-made artefacts and "mass" (see figure 18). Therefore, taking into account the results described in all previous experimental sections (5.3, 5.4 and 5.5), fundamental support is given to the original account of category specific deficits for living things, put forward by Warrington and Shallice (1984), of a differential involvement of sensory and functional properties in the semantic processing of sensory quality categories (living things and "mass" kinds) with respect to "non sensory quality categories" (man-made artefacts). Consequently, these findings cast doubts on Caramazza and Shelton's (1998) interpretation of category specific deficits in terms of the selective breakdown restricted to a distinct semantic domain: the observation of a deficit affecting to the same extent living things and "mass" is by no means accountable in terms of Caramazza and Shelton's position. Moreover, the widespread featural deficit related to sensory attribute knowledge, along with the generalised sparing of functional properties, involving thoroughly all semantic domains of living things, man-made artefacts and "mass" items, sharply contrasts to these authors' prediction of the non critical influence of featural knowledge in category specific deficits.

Feature verification tasks

However, the huge series of findings arisen from the feature verification task about living things and man-made artefacts (section 5.5.4) tends to match the data collected through the basic battery for the assessment of categorical knowledge associated to living things and artefacts (5.4) described in the second experimental section (see figure 19). A category specific deficit for living things arise at any of the different levels of analysis which the feature verification task makes possible. If the present findings related to MU's general knowledge of living things and man-made artefacts, are taken singularly into consideration, a clear deficit affecting living things is found, in contrast to the sparing of man-made artefacts semantics.

Table 67: MU's performance in attribute generation and feature verification tasks about living things, man-made artefacts and "mass" kinds

	Category	Encyclopaedic	Functional	Sensory
Attribute generation				
°Living	= *p>.1*	= *p>.1*	+ *p<.05**	= (-) *p>.1*
§"Mass"	= *p>.05*	= *p>.1*	= *p>.05*	× *p<.0001**
°Artefacts	= *p>.05*	= *p>.1*	= (+) *p>.05*	× *p<.005**
Feature verification				
°§Living	× *p<.0001**	× *p<.0001**	× (+) *p<.0001**	× *p<.0001**
§"Mass"	× *p<.0001**	× *p<.0001**	× (+) *p<.0001**	× *p<.0001**
°§Artefacts	= *p>.1*	= *p>.1*	= (+) *p>.1*	= (-) *p>.1*

*+: better than controls; ×: worse than controls; =: comparable to controls; (+): enhanced production with respect to sensory features; (-):decreased production with respect to functional features; *: significantly worse than patient controls.*
°: MU confronted to patient controls; §: MU confronted to normal controls.
For the three domains of living things, man-made artefacts and "mass" kinds, the convergence between findings obtained by different statistical methods is underlined; however, limitedly to the case of the attribute generation task, only the production of functional and sensory features was examined by using the two statistical procedures. In addition, in the case of the feature verification task, "mass" kinds knowledge was examined only through the adoption of the first statistical procedure

However, as stressed in sections 5.5.6.4 and 5.5.6.5, assuming a single case perspective, the direct comparison of MU's performance with sensory and functional attributes shows that the patient is significantly better in verifying questions about functional properties. The patient is instead below the chance level in the case of sensory feature verification regarding living things and also poorer, with respect to functional attribute verification, with man-made artefacts. From this perspective, therefore, the results obtained from the feature verification task about living things and man-made artefacts (section 5.5.6) does not strikingly contrast those obtained from the semantic attribute generation task about the same two classical domains (section 5.5.2). In fact, the cross-categorical influence of functional and sensory properties found in MU's spontaneous production of attributes (section 5.5.2), with an advantage of functional over sensory information across domains, is also observed, though only from a single case perspective, in MU's ability to make judgements about the same two types of information both as respect to living things and artefacts (section 5.5.6). Therefore, from these last considerations the findings resulting from the feature verification task about living things and man-made artefacts can still be considered in keeping with Warrington and Shallice's (1984) theoretical proposal. These data are also predicted by Farah and McClelland's (1991) computational model. In the authors' assumptions a lesion to the sensory component of the model would cause a deficit which massively impairs living things categorical and featural (sensory) knowledge, and, although to a minor extent, also man-made artefacts featural (sensory) knowledge: this is shown by the decrease in MU's performance related to functional vs. sensory attributes of artefacts (sections 5.5.6.4, tables 53 and 55).

However, when MU's performance is considered with respect to patient and normal controls, the absence of any effect of featural knowledge in this first feature verification task (section 5.5.6) seems to provide support to Caramazza and Shelton's (1998) theoretical account.

Furthermore, these findings are similar to those related to the second feature verification task (section 5.5.8), assessing the semantic knowledge associated to different classes of "mass" kinds. In this latter task, when patient MU is confronted to normal subjects, a generalised deficit is observed for all types of semantic features across "mass" categories, with no difference in his performance with both sensory and functional properties. However, as stressed in the methodological section (5.2), it should be pointed out that the use of normal subjects as controls to MU's performance has to be considered with caution, since normal controls tend to have an almost perfect performance on this task.

However, when only MU's performance is examined, as in single case studies, a massive impairment of the semantic knowledge related to sensory properties (section 5.5.8.5) of the item set (see figure 19), is found with respect to functional ones (section 5.5.8.4), an effect which undermines each of the three domains considered (30.9% correct with sensory information over the whole item set). In contrast, MU's performance with respect to functional knowledge of the semantic classes and subcategories of different "mass" kinds (66.2% correct over the whole set of items) is, in comparison, much better preserved. This result is therefore in keeping with the findings obtained through the attribute generation task about "mass" kinds (5.5.4), leading thus to the conclusion that MU's knowledge associated to the three "mass" sets shows striking similarities with the status of MU's semantics related to living things.

Further comments

Therefore, taken as a whole, the findings discussed in this experimental section (5.5) give in general support to the original Warrington and Shallice's (1984) proposal. This claim is further supported by the findings achieved in the first experimental section (5.3), when MU's knowledge of living things and "mass" categories was examined <u>together</u>. This leads to a substantial corroboration of a theoretical account stressing the fundamental role played by sensory properties in the elaboration of concepts such as living things and other novel categories, such as different "mass" kinds (Warrington and Shallice, 1984).

However, as pointed out in the introduction to this experimental section (5.5.1), the contrasting results obtained after the comparison of MU's performance to that of patient controls, in both the semantic attribute generation and the feature verification tasks about living things and man-made artefacts, might depend on the relevant differences which characterise the two tasks. In the attribute generation task, patients' spontaneous production is completely unconstrained, allowing them to retrieve from memory those semantic properties which, in their view, lead to the most exhaustive definition of the concept. On the other hand, in the feature verification paradigm semantic features pertaining or not to a concept are provided to patients by the examiner. Supposedly, in this latter case the availability of semantic information might sustain patients' judgement about the appropriateness of a property to a concept.

In MU's case, the availability of semantic features should help his performance at least with respect to man-made artefacts, whose knowledge, although not perfectly intact, might be still enough to perform the task. On the other hand, his widespread loss of knowledge associated to living things might make useless the provision of semantic information of any kind, leading therefore to a performance that would perfectly match Caramazza and Shelton's (1998) predictions. But one can ask why the provision to MU of, i.e., functional information (section 5.5.6.4), which in the case of living things is demonstrated to be at least partially intact (attribute generation task (section 5.5.2), does not enhance his performance with respect to patient controls. It might be likely that the type of functional information given to patients could not sort the desired effect because it is not "of the right kind".

As outlined in the introduction, the notion of function seems to have subtly different meanings in relation to the concept to which it is related. Providing the patient with information about the "use" of an animate kind (section 5.5.6.4) might be insufficient or, perhaps, misleading; however, the same type of information might be useful when artefacts (section 5.5.6.4) are concerned, given that these concepts might be "functionally" characterised in terms of the specific, often unique, "use" we make of them. As far as "mass" kinds are taken into consideration, the provision of "functional" information might still be useful, although perhaps not sufficient (section 5.5.8.4), because "mass" stimuli are usually characterised by a wide array of functions; therefore the piece of information given to patients might not be enough to drive them toward the correct answer. Given that, a qualitative analysis of the type of functional information presented to MU in the feature verification task, in the specific case of living things, seems quite reasonable, in order to highlight a possible preservation of differential types of functional information, which are hidden in the actual results. In fact, an analysis of the type of functional attributes of living things (table 53, section 5.5.6.4) provided to patients showed that functional properties containing information related to the action an animate kind can do (e.g.: "can the monkey climb trees?"), led MU to an advance in performance (129/201, 64.2% correct, slightly above chance). This was about twice as good than when functional features (e.g.: "does the cow produce milk?") not contained action-related information (15/39, 38.5% correct, clearly below chance). However, the patient control group showed a quite different pattern, being 174/201 (86.6% correct) when functional properties of living things contained action-related information, and 29.2/39 (74.9% correct) when functional attributes were not action-related. Therefore, MU's performance showed a difference of 25.7% with respect to the two subsets of functional semantic information, whereas in the case of patient controls the difference was much lower (11.7%).

Therefore, it might be likely that functional properties of living things, if related to action, can sustain, at least to some extent, the performance of patients with category specific deficits for living things, much more than the classical notion of function, that related to "use", might do.

However, this issue will be more directly addressed in the subsequent experimental section (5.6), where quite interesting, although provisional, findings are presented.

A final consideration has to be made as regards to the prediction Tyler et al. (in press) put forward of the total absence of difference (in the case of a category specific deficit for living things) between distinctive and shared information in the case of <u>sensory properties of man-made artefacts</u>, depending, in the authors' position, on the lack of intercorrelation which characterises both properties (section 3.3.3, point (iii) of their predictions). In the feature verification task (section 5.5.6) a different behaviour <u>was not</u> observed when MU's performance with respect to sensory information about man-made artefacts was compared to that of a group of patient controls, being both shared and distinctive semantic dimensions preserved. However, the examination of the single patient MU's scores as regards to his knowledge of the two types of dimensions related to sensory properties of man-made artefacts reveals a quite different pattern (see table 56, section 5.5.6.5): MU's knowledge of distinctive sensory properties (77.8% correct) related to artefacts is much more impaired relative to that of shared sensory properties (100% correct). This pattern is confirmed both by a χ^2 analysis, which demonstrates that the two sets of questions lead to a different behaviour in patient MU ($\chi^2=11.64$, df=1; $p<0.001$), and by an analysis of covariance, where a main effect of the Distinctive/Shared dimension is observed ($F=4.14$, df=1; $p<0.05$); furthermore, neither Dominance ($F=1.05$; df=1, $p>0.5$) nor Distinctiveness ($F=2.62$; df=1; $p>=0.1$) levels show to influence MU's performance. Therefore, in contrast to Tyler et al. (in press) another factor might be involved in MU's quite generally preserved performance with respect to man-made artefacts.

5.6 Investigation about the meaning/s of sensory and functional properties

5.6.1 Introduction

As was pointed out in the general introduction (section 1.1), a considerable effort was made by researchers in the assessment of semantic knowledge associated to two types of semantic properties, i.e. functional and sensory features in category specificity. However, a comparable amount of confusion about this issue is found in previous studies of the organisation and content of the semantic memory system, because very different findings were reported as regards to the knowledge of these conceptual features in patients (see sections 3.2.2 and 3.2.3). The final part of this work addresses several issues whose theoretical relevance should be ascertained to a much deeper extent in future studies. Thus, the findings and considerations drawn from this experimental section —<u>carried out exclusively on patient MU</u>— are only provisional and should be therefore considered just as suggestions for subsequent investigations of the role of attribute knowledge within the semantic memory system.

The first part of this experimental section (5.6.2) has three main purposes. Firstly, the knowledge MU has about <u>general vs. specific sensory features</u> of animals was assessed. Secondly, the knowledge the patient might demonstrate about the type of <u>function associated to sensory properties</u> of animals has been examined. Finally, MU's knowledge of the <u>action</u> which may characterise sensory properties of animate kinds was probed. Examples of the tasks used will be provided in the following sections.

As described before (section 5.5.6.5), it was observed that MU's ability to verify statements about general and specific sensory properties was similar for both distinctive (specific) and shared (general) features of living things, being MU equally impaired both in comparison to normal subjects and patient controls (see table

56). It should be observed, however, that in the feature verification task MU showed a clear difference with respect to both types of sensory properties, being 61.1% correct with general and 36.7% correct with specific features (section 5.5.6.5). Therefore, in order to investigate in deeper detail this first issue, a new task, based on question answering, was devised. The patient was asked to decide whether general and specific sensory features belonged to a list of animals; furthermore, general sensory properties of animals were subdivided into visible and non-visible features. In order to address the second and third points, another set of questions was devised and administered to MU with the purpose of assessing his knowledge of both the function and the action associated to sensory features of animals: again in this cases general and-specific sensory features were taken into consideration, and MU's performance as regards to two "novel" types of sensory properties was therefore examined (the stimulus sets adopted in this experimental section are listed in appendix E).

A related topic, regarding specifically objects' knowledge, was addressed in the second part of this experimental section (5.6.4). As stressed in many parts of this work, functional properties are often associated to different types of meanings. Hence, the effort was made here of distinguishing furthermore the notion of "pure function", such as "what an object is used for" or "what an object can do", from the notion associated to the "way an object is used", which implies the knowledge we have of the action, or series of actions, performed during the manipulation of an object (the stimulus sets used in this sections are listed in appendix E).

An array of tasks was devised in order to highlight whether these two types of knowledge can be differentiated in a patient, MU, who demonstrated a relatively spared knowledge of man-made artefacts: the aim of this investigation was that of establishing, at least to some extent, whether MU's knowledge of artefacts is supported by the processing of specific types of information, either the function or the action related to an object, or both.

5.6.2 Knowledge of general vs. specific sensory features of animals

5.6.2.1 Questions about general vs. specific sensory attributes

MU was asked to provide an answer to a series of orally presented yes/no questions about general and specific sensory properties of animals, such as "does the animal ... have lungs/tail?". A first set of questions related to animals was taken from Garrard et al.'s database (unpublished), since the authors already differentiated between general and specific attributes ("shared" and "distinctive" features in the authors' terms) of sensory features (e.g.: general sensory features: "Does the lion have eyes?"; specific sensory features: "Does the lion have a mane?"). In addition, a new and much wider set of 448 questions was proposed to MU, following the same criterion adopted by Garrard and colleagues of separating general vs. specific features of animals. Frequency norms for general and specific sensory features related to the new set of questions are presented in table 68. As expected, general sensory features have been shown to be more frequent than specific ones; therefore, the obtained results should be reconsidered in terms of the potential influence of this factor. A major problem arising from the item set adopted in this section is that only frequency was taken into consideration. However, other factors, such as item familiarity, might be found to influence patients' performance. Therefore in future studies about the differences between general and specific sensory information, the sets of featural information adopted should be closely controlled with respect to a wider series of potentially confounding variables.

It should be added that in the case of specific sensory properties, semantic features were collected from two groups of animals, which could be differentiated on the basis of their relative visual similarity. Therefore, two groups of animals, either highly similar in shape (e.g. cow, zebra, deer) or sharply dissimilar (e.g. tiger, kangaroo, elephant) were taken into account (a list of the animals selected is presented in appendix E), and a series of their specific sensory attributes was prepared. Each animal was then coupled with a specific sensory feature which may or may not pertain to the animal (e.g.: high similarity: "Does the cow have udder?/Does the cow have a very short tail?"; low similarity: "Does the tiger have stripes?/Does the tiger have a very long muzzle?"). If the shape of animals is a relevant factor in visual identification, in contrast to other sensory quality properties such as colour and texture, which are generally specific features, a difference might be found in MU's performance with the two sets of visually similar and visually dissimilar animals.

Table 68: Frequency norms for the new set of questions about sensory properties of animals

		Frequency
General sensory features	Mean	3.96
	sd	*1.27*
Specific sensory features	Mean	2.45
	sd	*1.72*

For the means used see legend to table 8.

Moreover, in order to probe a possible distinction between visible and non-visible sensory properties of animals, a new set of questions, limited to general features, was subdivided into two subsets of 112 items each (e.g.: visible features: "Does the deer have a mouth?"; non-visible features: "Does the deer have lungs?"). However, the same procedure was unlikely to be done in the case of specific sensory features, because they were mostly visible features. This factor was taken into account since the patient's performance might be influenced by the relative visibility of sensory features. Table 69 provides the raw scores and percent of MU's correct answers in these tasks.

Table 69: Yes/no questions about general and specific sensory properties of animals

Sensory features	**General**		**Specific**	
	Raw data	Percent	Raw data	Percent
Questions from Garrard's et al. database	50/60	83.3	23/60	38.3
New set of questions	188/224	83.9	51/224	22.8
Total number of items	238/284	83.8	74/284	26
Visible	83/112	74.1		
Non-visible	108/112	96.4		

Both in the first and the second sets of questions (see table 69), MU was much more accurate as far as general sensory features of animals were concerned (about 84% correct overall), whereas a dramatic decrease in his performance was observed (χ^2=191.3, df=1, p<0.00001) when he had to deal with specific sensory features (about 30% correct overall). Since the first set of questions was taken from Garrard's et al. database, an examination could be performed regarding the influence of distinctiveness and dominance measures on MU's performance. The two factors entered as covariates in an analysis of variance, and, whereas no significant effect of Dominance was found (F=3.68; df=1; p>0.05), Distinctiveness seemed to have a role in MU's performance (F=10.23; df=1; p<0.005). Moreover, the difference between general and specific sensory features sets in the first group of questions, already observed above (table 56, sections 5.5.6.5 and 5.6), received further support by the analysis: in fact, a main effect of Distinctive/Shared features was found in the patient's performance (F=25.47; df=1; p<0.001).

A closer examination of the second, much larger, set of questions was then carried out and the potential influence of word frequency on MU's scores was considered. An analysis of covariance showed that Frequency (F=1.4; df=1; p>0.1) was not a predictor of MU's performance over the whole set of 448 questions. However, a main effect of Feature Type (F=123; df=1; p<0.001) highlighted the large discrepancy between general and specific sensory features, already observed with respect to the first set of Garrard's questions. Furthermore, since specific sensory features were collected from two groups of animals, differing in their relative degree of visual similarity, the effect of this factor was also examined: however, neither an influence of Word Frequency (F=0.61; df=1; p>0.1), nor, and more importantly, an effect of Similar/Dissimilar shapes (F=0.015; df=1; p>0.5) were found to affect MU's performance. This last result seems to suggest that shape has not a relevant role in MU's visual identification of animals: in visual processing, therefore, other properties might be fundamental as regards to animal recognition, such as truly "sensory quality" properties which do not include information about shape, like colour and texture: however, in this experimental work this issue was not further addressed.

In addition (see table 69), the patient's performance was almost at ceiling with non-visible features (96% correct), while MU's ability to judge visible sensory features (74% correct) was relatively affected (Wilcoxon matched pairs: z=-10.3, p<0.0001). An analysis of covariance demonstrated again that Word Frequency did not influence MU's performance (F=1.91; df=1; p>0.1). However, as demonstrated already through the Wilcoxon analysis, a main effect of Visibility of features was found (F=8.62; df=1; p<0.005). This observation shows that, although non-visible properties of animals (such as heart, lungs, stomach) are usually more frequent than visible properties (such as tail, fur, horn), MU did not show an effect of frequency with this item set. However, it might be likely that other factors, such as item familiarity, have an influence on the patient's performance. Therefore, this result should be considered with caution.

5.6.2.2 Questions about the function of sensory attributes

In a further task MU's knowledge of the function of general vs. specific sensory features of animals was probed. General features are those properties which are commonly shared ("prototypical") by the large majority of animals, whereas specific attributes are uncommon (less "prototypical") to the majority of the exemplars. The patient had to provide a verbal description of the function related to a series of general (e.g.: " What is the function of nose in animal ...?") and specific (e.g.: " What is the function of claws in animal ...?") sensory properties of animals, orally presented to the patient. The accuracy of his responses was analysed by two independent judges, and those answers on which the two judges were not in agreement were discarded. MU's answers were mostly omissions, but in some instances he provided wrong, unclear or too general answers (e.g.: general features: question "What is the function of the coat?"/answer *"To be protected from cold weather"* —accepted as correct; question "What is the function of bones?"/answer *"To live"* —discarded; specific features: question "What is the function of canine teeth?"/answer *"To tear to pieces a prey "* —accepted as correct; question "What is the function of plumage?"/answer *"To hear better"* —discarded).

Table 70: MU's knowledge of the function associated to general and specific sensory properties of animals

General		**Specific**	
Raw data	Percent	Raw data	Percent
25/28	89.3	10/30	33.3

As described in table 70, MU seemed to be generally able to supply accurate functional descriptions about general sensory features of animals (89% correct), in contrast to a poorer performance (33% correct) with specific sensory features (χ^2=18.9, df=1, p<0.0001). Since word frequency norms were available for the two featural item sets adopted, an analysis of covariance could be performed regarding MU's scores in this task. A main effect of Feature Type (F=12.27; df=1; p<0.001) was observed, providing new evidence to the findings described in the previous section (5.6.2.1): MU is influenced by the type of sensory properties also when asked to provide information about the function of these sensory features, being much better in the case of general properties relative to specific ones. However, an effect of Word Frequency was also found (F=12.35; df=1; p<0.001), and therefore the influence of this factor on the present results must be considered carefully.

5.6.2.3 Questions about the action of sensory attributes

A further attempt aimed at disentangling the notion of function from that of the action related to sensory attributes of animals, such as "how a sensory attribute moves", had been addressed in a subsequent task. A subset of general (e.g.: "How does animal ... move ears?") and specific (e.g.: "How does animal ... move wings?") sensory attributes of animals was selected, and patient MU was required to provide an accurate description of the movement which characterises a given sensory property. MU's answers underwent the analysis of two independent judges: the only answers which led to an agreement between the two judges were kept for the analysis. In this task, MU's wrong answers were only omissions (examples of MU's correct answers: general features: question "How does animal ... move teeth?"/answer *"It opens the mouth and then it draws up and down and with circular movements the teeth"*; specific features: question "How does animal ... move claws?"/answer *"It can pull out or draw back claws"*).

Table 71: MU's knowledge of the action associated to general and specific sensory properties of animals

General		Specific	
Raw data	Percent	Raw data	Percent
18/18	100	15/20	75

In general, MU's ability to provide accurate descriptions about the movements characterising sensory properties (see table 71) was quite spared (33/38, 86.8% correct over the whole set of general and specific features). His performance with respect to specific sensory attributes of animals, though much more improved with respect to previous tasks discussed in this section, (75% correct) was significantly different (χ^2=4.9, df=1, p<0.05) from that related to general properties (100% correct). Also in this case an analysis of covariance could be performed on MU's scores with respect to the two item sets, because frequency values were available for both types of features. Interestingly, in contrast to the χ^2 analysis, MU's performance was comparable as regards to both sets of items, since a main effect of Feature Type (F=1.67; df=1; p>0.1) was found to be not significant; furthermore, the patient was not influenced by Word Frequency (F=3.2; df=1; p>0.05) in performing this task.

5.6.3 Summary

In the first part of this experimental section MU's semantic knowledge of sensory features of animals was carefully investigated (section 5.6.2). The patient's knowledge of general sensory properties of animals is much more intact than that associated to specific attributes (section 5.6.2.1), and not influenced by word frequency, as far as the second set of 448 questions (table 69) was considered. MU's ability to verify statements regarding general sensory features of animals seems in contrast with some results obtained in the feature verification task previously described in section 5.5.6. However, in that task his performance with general and specific sensory features of living things (section 5.5.6.5, table 56) was compared to that of normal subjects and patient controls, and he was found to be severely impaired as respect to both groups. Anyway, it should be noted that, also in the feature verification task, MU's knowledge of general (shared) sensory features, although defective (about 61% correct) in comparison to patient controls, was in fact better than that related to specific (distinctive) sensory features, which was instead severely affected (about 37% correct).

Furthermore, the features adopted for the specific sensory attribute set (second set of questions, table 69) were drawn from two groups of animals differing in their relative degree of visual similarity (shape). Even though MU's knowledge of specific information is found to be greatly impaired with respect to that related to general features, an effect of visual similarity of animals was <u>not</u> found (section 5.6.2.1). Therefore, the shape an animal has does not seem to play a major role in its visual processing, while this role should be more likely accomplished by an analysis of other sensory properties, which are more closely associated to the general definition of what an animate kind is; in addition, MU's knowledge of visible sensory attributes of animals is not as good as in the case of non-visible features. As predicted by Tyler and co-workers (in press), it is likely that MU's category specific deficit for living things does not allow the patient to distinguish between exemplars of the category, due to his loss of specific sensory features, but allows him to recognise whether an item is or is not an animal, because he can still deal with general sensory properties common to all members of the animate class.

As a whole, this result matches the predictions of Tyler and Moss (1997) and Tyler et al. (in press), of an advantage of general sensory feature knowledge of living things with respect to specific in patients showing a category specific deficit for living things. However, it has to be stressed that general sensory features are usually easier than specific ones: in fact, they are more frequent (although no effect of frequency was observed as respect to the second set of questions adopted —see table 69) and probably much more familiar than specific sensory features. Further studies, which will take into account the influence of familiarity, might provide a more exhaustive account of the discrepancy found between the two types of features.

When MU's knowledge of the <u>function</u> of sensory attributes is examined (5.6.2.2), an advantage is again observed with regard to general features, in contrast with specific properties, for which functional knowledge is reported to be severely defective. However, a great effect of word frequency is found to affect MU's performance in this task, suggesting that more controlled studies on this matter are required before drawing more definite conclusions. In the investigation of the patient sensory knowledge great attention has to be put on the distinctive/shared dimension of features information, as Tyler and co-workers reasonably point out, but, as argued in this and also in a previous section (5.6.2.1) the relevance of other factors has also to be controlled: in fact, as outlined above, general sensory features are obviously much more frequent, and, supposedly, familiar, than specific sensory features.

At variance with the above pattern of findings, MU's knowledge of the action associated to both general and specific sensory features (section 5.6.2.3) was quite preserved, although the patient was significantly better with general than with specific properties, a finding that was however in contrast to the results of an analysis of covariance. In addition, the fact that the patient's performance was not influenced by word frequency might add further support to the view that his ability to deal with action-related information, as briefly shown also in section 5.5.10, is well preserved also in the case of a class of stimuli, animals, whose knowledge was found to be highly disrupted in a large array of preceding tasks.

5.6.4 Knowledge of function vs. action in objects

The notion of function seems to differentiate according to the semantic category taken into consideration. In the case of artefacts "function" might be related to the knowledge of "what an object is used for" ("true function") as well as to the knowledge of "how an object is used" ("affordance to action"), and the two notions should be disentangled, in order to explore further the reasons of MU's good behaviour with respect to functional features of man-made artefacts in the feature verification task (section 5.5.6.4). In this study, patient MU showed a category specific deficit thoroughly affecting the living things domain. Although MU's knowledge of man-made artefacts was relatively spared, is his performance with artefacts homogeneous?

In order to assess in more detail MU's semantic knowledge of man-made artefacts, a visual confrontation naming task was devised (section 5.6.4.1, table 73). 300 coloured pictures of objects, divided in three different sets, were collected and visually presented to patient. One third of the objects were characterised by a strong affordance toward a single action (e.g. hammer, saw); 100 objects had a mild affordance toward a single action (stove, television) and the remaining 100 did not suggest any affordance toward a well defined action (picture-frame, street-lamp). To further examine the influence of function- and action-related information on MU's performance with man-made artefacts, a novel series of tasks was devised (see table 74), employing a unique set of 60 black and white man-made artefacts stimuli, subdivided in three subsets of items (sections 5.6.4.3 and 5.6.4.4); in table 72 the normative data regarding this item set are provided. The three sets of items, though balanced as much as possible, differed in terms of Word Frequency (F=5.6; df=2; $p<0.01$) and Item Familiarity (F=3.8, df=2; $p<0.05$). However, the three sets were not different in terms of Visual Complexity (F=0.56; df=2; $p>0.05$).

Table 72: Frequency, familiarity and visual complexity means and sd for the 60 items used in the four subsequent tasks

		Frequency	Familiarity	Visual complexity
Whole set	Mean	1.65	1.15	0.97
	sd	*1.29*	*0.28*	*0.32*
Same action/same function	Mean	2.3	1.23	0.91
	sd	*1.21*	*0.31*	*0.24*
Same action/different function	Mean	1.06	1.02	1.02
	sd	*1.04*	*0.23*	*0.36*
Different action/same function	Mean	1.57	1.21	0.99
	sd	*1.34*	*0.24*	*0.35*

Frequency norms were taken from Dizionario di Frequenza della Lingua Italiana, CNR (unpublished); familiarity and visual complexity were instead collected from a group of 10 normal subjects, matched to MU in terms of sex, education and age, as described in table 38. Normal subjects were asked to rate on a five point scale the familiarity and visual complexity of the pictures comprising the item set used.

Therefore, in section 5.6.4.2 a new visual confrontation naming task was administered to patient MU; stimuli were coloured drawings, presented one at a time, with unlimited time for answer. The same stimulus set was adopted to build a word-to-picture matching task (section 5.6.4.2): 30 pairs of stimuli were visually presented in different test sessions in a random order to the patient, who had to identify the requested target. The choice to use a very limited number of stimuli on each trial was taken principally in order to ascertain whether MU was able to correctly identify each item, so that the stimuli could be used in two subsequent critical tasks, a questionnaire about objects function (section 5.6.4.3) and a further questionnaire about objects action (section 5.6.4.4). Both questionnaires were organised as follows: two stimuli were simultaneously presented in visual modality to the patient, who was asked to decide whether the pairs of stimuli were characterised by either the same function ("Are the two objects used with the same purpose?") or the same action ("Are the two objects used making the same kind of movement?"). Both questionnaires comprised 30 pairs of objects: (i) 10 pairs were characterised by both objects sharing the same function and used through the same action/movement (e.g. knife/saw); (ii) in other 10 trials the two objects had the same function but were used with a different type of action (e.g. gas-lighter/lighter); (iii) the last 10 pairs adopted objects that were manipulated by the same action, but had different functions (e.g. calculator/radio-control). The visual confrontation naming and the word-to-picture matching tasks were presented in different testing sessions, to avoid effects attributable to practice with the item set. However, the two questionnaires were presented twice to MU, in four separate sessions overall.

5.6.4.1 Visual confrontation naming and identification task

A visual confrontation naming task employing three sets of objects characterised by different degrees of affordance to action was administered to MU. Given the large number of stimuli (300 items), and the fact that MU's naming skills were in general mildly affected by word finding problems, both his naming performance and his ability to accurately identify the items were evaluated. MU was presented visually with coloured drawings and had unlimited time to provide an answer. Whenever he could not retrieve the name of a stimulus, he was encouraged to provide a description of the object. MU's answers were then evaluated by two independent judges, and only those which could be undoubtedly recognised as the correct name or as a good description of an item by both judges were taken into account. Table 73 presents the raw scores and percent of MU's correct answers both in the naming and identification versions of the task.

Table 73: MU's performance in naming and identification of high-, mild- and no-affordance objects

	Naming		Identification	
	Raw data	Percent	Raw data	Percent
High affordance	69/98	70.4	92/98	93.9
Mild affordance	60/97	61.8	81/97	83.5
No affordance	59/95	62.1	74/95	77.9

As shown in table 73, MU's naming scores were characterised by a similar pattern of performance as regards to the three sets of items, and no statistical difference was observed between high, mild and no affordance objects (χ^2=2.02, df=2, p>0.1). However, MU's ability to identify the stimuli showed a feeble but statistically significant tendency (χ^2=10.1, df=2, p<0.01) to decrease from high affordance objects (94% correct) through mild (83% correct) and finally to no affordance objects (78% correct). Also, when asked to mime the use of the 100 high-affordance objects, MU had no difficulties in performing the task, being 100% correct.

These preliminary findings might highlight a possible influence on MU's performance of information related to the action the form of an object suggests. However, the results do not allow a direct comparison of the relative weight semantic information associated to action and knowledge related to function might have as regards to patient's performance with the man-made artefacts class. A preliminary attempt to examine this issue was then performed in the following sections.

5.6.4.2 Visual confrontation naming and word-to-picture matching task

MU's performance in two tasks involving man-made artefacts (see table 74) showed that he was relatively preserved in a visual confrontation naming task (78.3% correct) and almost perfect in a word-to-picture matching task (91.7% correct).

MU's performance could not be compared to that of a control group; therefore, in order to control the influence on his naming performance of factors held to be relevant, as already described in a previous chapter (section 3.3.2), an analysis of covariance was carried out on MU's responses to the naming task. He was not influenced by Word Frequency (F=0.39; df=1; p>0.5) or Visual Complexity (F=0.8; df=1; p>0.1) of the item set, whereas an effect of Familiarity was observed (F=4.4; df=1; p<0.05).

His generally spared performance in the two tasks means that the items can be used to assess MU's semantic knowledge about the function- and action-related information associated to the same set of items.

Table 74: MU's performance on four new tasks on objects

	Raw data	**Percent**
Visual confrontation naming	47/60	78.3
Word-to-picture matching	55/60	91.7
Decision on function (1st session)	18/30	60
Decision on function (2nd session)	17/30	56.7
Decision on action (1st session)	25/30	83.3
Decision on action (2nd session)	27/30	90

5.6.4.3 Decision on objects function

MU's overall ability to decide whether two objects share the same function (see table 74) was defective both in the first (60% correct) and in the second (56.7% correct) testing sessions. A tendency to a statistically significant difference was observed when MU's overall performance in the two testing sessions regarding the three subsets of items characterising the task (described in table 75) was examined (Kendall coefficient of concordance: W=0.9, df=2; p=0.06). In fact, he was much more defective on function decision with respect to the set of objects characterised by "same action/different function" than in the remaining two subsets.

In a subsequent step, a comparison among the three different item sets, administered twice to the patient, in the decision on object function (see table 75) was performed. A tendency to significance was observed in the first testing session when couples of objects characterised by <u>same action/same function</u> were compared to pairs of objects regarded as <u>same action/different function</u> (Wilcoxon matched pairs: z=-1.82, p>0.06); anyway, the item sets defined as <u>same action/different function</u> vs. <u>different action/same function</u> were contrasted, MU's scores were significantly different (Wilcoxon matched pairs: z=-2.02; p<0.05). However, in the second session the difference between <u>same action/same function</u> set with <u>same action/different function</u> set (Wilcoxon matched pairs: z=-2; p<0.05) was statistically significant. Furthermore, the comparison between <u>same action/different function</u> and <u>different action/same function</u> sets (Wilcoxon matched pairs: z=-2.2; p<0.05) highlighted again a statistically significant difference.

Since the three item sets adopted to prepare the tasks described in the present, the preceding (5.6.4.2) and the following (5.6.4.4) sections were different as regard to word frequency and item familiarity (section 5.6.4, table 73), an analysis of covariance was performed on MU's performance in the decision on object function task for both testing sessions. As far as the first session was concerned, a main effect of Item Set was observed (F=3.4; df=2; p<0.05); similarly, a significant effect of Item Set was found in the second session (F=7;df=2; p<0.005). Therefore, the three sets of objects seems to lead to a clearly different performance in patient MU. In addition, Item Familiarity (F=0.05; df=1; p>0.5) and Word Frequency (F=1.47; df=1; p>0.1) were found to have <u>no</u> effect on MU's performance with the three sets of objects, while Visual Complexity of the stimuli seemed to have some role on his ability to perform the task (F=4.07; df=1; $p<0.05$). In the second session, Familiarity (F=1.4, df=1; $p>0.1$) and Frequency (F=2.4; df=1; $p>0.1$) were found to have no influence on MU's performance; again, however, Visual Complexity had a significant influence on the patient's performance (F=4; df=1; $p<0.05$).

A consideration may be perhaps drawn from this last finding: as stressed by De Renzi and Lucchelli (1994) and Tyler and colleagues (Tyler and Moss, 1997; Tyler et al., in press), the form an object has is related to its function. In some way, visual complexity might influence the patient's processing involved in the decision about the function of pairs of objects, just because an analysis of the form of an item becomes relevant in the attempt to retrieve information relative to the object function.

Table 75: MU's performance in the two decision tasks

	Same action/ same function	Different action/ same function	Same action/ different function
Decision on objects function (1st session)	7/10	8/10	3/10
Decision on objects function (2nd session)	7/10	8/10	2/10
Decision on objects action (1st session)	9/10	8/10	8/10
Decision on objects action (2nd session)	10/10	8/10	9/10

5.6.4.4 Decision on objects action

MU's ability to perform a decision on the sameness of two objects action (see table 74) led to an overall preserved performance (83.3% correct) in the first testing session and also in the second one (90% correct). The examination of MU's performance in the two testing sessions with respect to the three sets characterising the task taken as a whole (see table 75) did not lead to a significant difference between item sets (Kendall coefficient of concordance: W=0.33; df=2; $p>0.1$). The three sets of items in the decision on object action task seems thus to be highly comparable (see table 75).

Again in this task the potential influence of variables such as frequency, familiarity and visual complexity on MU's performance with the three item sets was assessed through an analysis of covariance. Both in the first (F=0.008; df=2; p>0.05) and the second testing sessions (F=2; df=2; p>0.1) a non significant main effect for Item Set was observed. Moreover, no significant influence of three factors, Item Familiarity (F=0.097; df=1; p>0.5), Word Frequency (F=0.013; df=1; p>0.5) and Visual Complexity (F=1.062; df=1; p>0.1), was found to affect MU's decisions about object action in the first session of testing. The same results were obtained as far as the second testing session was considered: Familiarity (F=0.71; df=1; p>0.1), Frequency (F=0.15; df=1; p>0.5) and Visual Complexity (F=0.008; df=1; p>0.5) were shown to have no influence on the patient's performance in this task. In contrast to what observed as regards to decision about objects' function, visual complexity does not seem to play a role in this task.

In keeping with Buxbaum and Saffran's (1998) position about the fundamental role of affordance to action information in man-made artefacts processing, it may be likely to conclude that, during decisions relying on object action information, a detailed analysis of objects appearance is not a relevant factor, as demonstrated by the absence of effect of visual complexity in MU's performance. In contrast, the examination of the visual structure of objects seems to be fundamental in tasks involving the engagement of object function information, as was put in evidence by the statistically significant influence of visual complexity on MU's performance (section 5.6.4.3). This last finding seems to support De Renzi and Lucchelli's (1994) and Tyler and colleagues (Tyler and Moss, 1997; Tyler et al., in press) position of a direct relation between form and function in object processing.

5.6.5 Summary

MU's semantic knowledge about man-made artefacts was found to be relatively preserved with respect to that associated to living things and "mass" kinds in a large series of tasks administered throughout this work (sections 5.3, 5.4 and 5.5). However, an attempt was made in this last section in order to verify whether his relatively spared performance with objects is sustained by processes relaying more on either functional information or knowledge related to action. A preliminary series of findings suggests that MU's performance in objects' identification is influenced by the degree of affordance objects have, with an advantage for artefacts strongly suggesting a unique, well defined, action (section 5.6.4.1). A subsequent series of tasks was devised in order to disentangle, if possible, the effects of functional (5.6.4.3) and action (5.6.4.4) information. When required to decide whether pairs of objects share the same action, MU is quite accurate (83.3% correct in the first session; 90% correct in the second). In contrast, he has some difficulties when his decision has to be based on the function of couples of objects (60% correct in the first session; 56.7% correct in the second session). Moreover, it might be suggested that a decision related to action does not seem to be influenced by the fact that objects share or not the same function (see table 75). In contrast, a decision about function seems to be more difficult, particularly when pairs of objects have different functions (table 75). As pointed out by De Renzi and Lucchelli (1994) and Tyler and co-workers (Tyler and Moss, 1997; Tyler et al., in press), information about the form an object has might be relevant in order to differentiate between couples of objects sharing the same function. Although a task specifically controlling the shape of objects has not been devised in this experimental part (5.6.4), some insight may come from the effects the factor of visual complexity has on the two last task administered. On this ground, visual complexity is found to influence the discrimination process based on function (5.6.4.3) as predicted by De Renzi and Lucchelli (1994) and Tyler (Tyler and Moss, 1997; Tyler et al., in press), whereas this same factor, on the same set of stimuli, is found to have no influence in the decision about action (5.6.4.4), where the role of another source of information, that of affordance to action, might instead have a prominent role (Buxbaum and Saffran, 1998).

5.6.6 General conclusion

The fourth experimental investigation of MU's semantic memory system was twofold. In the first part (section 5.6.2), the semantic knowledge of sensory features of animals was examined, while in the second (section

5.6.4) object knowledge was investigated. In both cases, the attempt was made to identify peculiar aspects of the semantic processing which can sustain patient's performance across tasks.

MU's knowledge of general sensory features of animals is preserved, in contrast with that related to specific properties (5.6.2.1). Notably, patient's knowledge of functional aspects of sensory features (5.6.2.2) is spared only in the case of general attributes, as predicted by Tyler and Moss (1997) and in contrast to De Renzi and Lucchelli's (1994) position, who do not hypothesise the existence of differential types of sensory features in the case of living things. In contrast, MU's knowledge of action-related information (5.6.2.3) is preserved both in the case of general and specific sensory features of animals. This last result does not provide support to any theoretical account, since no theorists predicted a differential role of action- or function-related information in the processing of sensory features of animals. However, this result cast some doubts on Tyler and colleagues' position of the preservation of general sensory properties (biological functions in the authors' terms) in living things, since, although this was proved to be true (table 69), factors such as frequency seem to influence the patient's performance on these tasks (section 5.6.2.1); more importantly, no effect of visual similarity regarding the shape of animals was found to influence the performance of patient MU (section 5.6.2.1). These results suggest that general biological functions might be truly resistant to damage, as predicted by Tyler and co-workers. However, these authors did not clarified the <u>nature</u> of the relation which should connect general sensory properties to their biological functions. From the findings of this section (5.6.2.1), it seems likely to exclude that the shape of an animal might cover this role, and therefore further studies are needed to clarify this issue.

In the second part of this experimental section (5.6.4), MU's semantic knowledge of objects is examined. Objects are characterised both by functional- and action-related information: in the last experimental section it was observed that his performance might be much more supported (5.6.4.4) by processing based on action-related information, as hypothesised by Buxbaum and Saffran (1998), although functional information can perhaps influence to some extent his generally good performance with man-made artefacts. Furthermore, the absence of any effect of visual complexity on his performance in the action decision task, might suggest that a visual analysis of objects is only minimally involved in this task with respect to tasks requiring the retrieval of functional knowledge. However, visual processing might play a role in the function decision task, where an effect of visual complexity was found: this last result might provide support to De Renzi and Lucchelli's (1994), Tyler and

Moss's (1997) and Tyler et al.'s (in press) view, since these authors claim that the form of an object, its visual appearance, entertains a direct link to its function.

In conclusion, although very different sources of semantic knowledge were examined, namely sensory features of animals and knowledge related to man-made artefacts, a specific type of information seems to be constantly unaffected in patient MU: the knowledge associated to action.

On this matter, an essential theoretical issue should be however addressed: MU's preserved ability to deal with action-related concepts might reflect either the role of a separate component within the semantic memory system, committed to the elaboration of action semantics, or the operation of a module separated from the conceptual system, which is triggered by affordance information. In Hodges et al. (1999), the view is held of an essential role of the parietal-dorsal pathway in processing action information without reference to object-specific conceptual knowledge. It should be noted, however, that in their study action knowledge was probed through the actual usage of objects. In MU's case, although praxis skills were shown to be intact on an informal assessment (5.6.4.1), action knowledge was tested principally through tasks that did not imply the real use of objects. Whether the tasks administered to MU and, obviously, his generally spared performance, rely on processing engaging either the temporal lobe system or the parietal pathway has to be yet clarified.

Chapter 6: General discussion and conclusions

6.1 Introduction

The present work describes the performance of a group of presumed HSE patients assessed through a wide series of tasks investigating across different modalities and with a remarkably large variety of stimuli the organisation of their semantic knowledge of three domains, namely living things, man-made artefacts and "mass" kinds.

All patients who entered the study had suffered from a probable episode of herpes simplex encephalitis. This condition was investigated because of the category specific effect of relative preservation of man-made artefacts identification, which has been observed in a considerable number of patients with this aetiology. As extensively described in the methodological section, this choice was motivated by the fact that all patients suffered from the same neurological disease, being thus comparable in terms of aetiology. Although it is known that HSE can produce patterns of neurological impairments that may differ to some extent, depending in particular on the rapidity of the diagnosis and the subsequent pharmacological treatment, all the patients who were examined in this study presented memory deficits and, more importantly, were, as a group though not as individuals, broadly comparable on their naming performance with man-made artefacts. This observation is of extreme relevance for the purposes of the present study, since, as shown in experimental section 5.3, the patient controls, who did not show a remarkable category specific deficit, were however matched to MU, the key patient of this study, on the most critical factor, namely their performance with man-made artefacts. Patient MU's knowledge of three semantic domains —man-made artefacts, living things and "mass" kinds— was therefore examined over four subsequent experimental investigations. Both patient's <u>categorical</u> (experimental sections 5.3 and 5.4) and

<u>featural</u> knowledge (experimental section 5.5 and, limitedly to living things and man-made artefacts, section 5.6) associated to the three semantic categories underwent a close assessment. Patient MU's performance was compared to that of the patient control group whenever tasks involved the semantic categories of living things and man-made artefacts, while the use of normal subjects as controls was necessary in the case of tasks involving "mass" stimuli, with the only exception of the experimental investigation described in section 5.3, in which HSE patients could be compared to MU in the whole series of empirical tasks.

In the literature, as described in sections 3.2.1 and 3.2.2, category specific deficits were reported from an array of patients suffering from very different aetiologies, and the characteristics and extent of their deficits often differed from one case to the other. Moreover, patients' deficits were assessed through the adoption of tasks and stimuli that showed huge dissimilarities, making difficult the attempt of achieving a comprehensive picture of this semantic memory deficit. Moreover, category specificity has often been used as a label for deficits affecting either semantic memory, which leads to an impairment of both production and comprehension of a selective conceptual category, or pure naming deficits, where the damage was shown to be limited to word production. However, in the present study category specificity will be considered as an impairment of semantic memory, leading to a damage specifically involving the production and comprehension of concepts related to the broad category of living things, and affecting both the verbal and visual modalities of input presentation.

Category specific deficits in herpes encephalitis patients usually lead to a loss in patient's ability to deal with concepts associated to the living things domain (section 3.2.1), but this definition lacks of exhaustiveness. Whilst in some cases a deficit has been reported to affect the whole semantic class of living things, cases are described of patients whose deficit is limited to knowledge of delimited subcategories belonging to the natural kinds domain. In addition, patients presenting a categorical disruption of the living things category, were often reported to show an impairment in other quite different domains of knowledge, the most frequently described being foods and musical instruments.

Therefore, these previous reports motivated the attempt to achieve in this study a more comprehensive understanding of categorical deficits, investigating a large array of subclasses belonging both to the natural and also other semantic domains. Category specific deficits led to a long-lasting debate about the possible theoretical account of this semantic memory impairment. As reviewed in section 3.3, several contrasting theories were proposed by investigators, the possibility of disentangling some of the most relevant predictions following from different positions was pursued in this work, and particular attention was devoted to two contrasting theories, the one put forward by Warrington and Shallice (1984) in their original account of the phenomenon, and the recent proposal of Caramazza and Shelton (1998). As extensively described in the theoretical section (3.3), the two theories sharply differ in their interpretation of category specific deficits, held to be determined by the differential role of underlying semantic processing (sensory vs. functional) in Warrington and Shallice's view, where living things are thought to be dependent on sensory information and man-made artefacts on functional properties. Therefore in these authors' view a category specific deficit for living things will impair the knowledge of this category because of a damage to the processing of semantic sensory properties, while a selective deficit for man-made artefacts will be ascribed to the disruption of functional information processing. In contrast, Caramazza and Shelton (1998) proposed that category specific deficits either for living things or man-made artefacts arise because of a selective disruption affecting the semantic memory system that is held to be organised categorically. Therefore, in these authors' view the role of different semantic properties, such as functional and sensory information, is not critical, while the sharp differentiation between representations belonging to the two semantic domains is claimed to be fundamental. In their opinion therefore, a category specific deficit for a given semantic domain will not be associated to a deficit of the sensory or functional knowledge. To test directly the implication of these two contrasting positions, that of Warrington and Shallice (1984) and that of Caramazza and Shelton (1998), an effort was made in order to assess with different experimental paradigms both categorical and featural knowledge of patients. Moreover, the introduction of a novel category, which is held to rely on sensory processing, was thought to be critical in order to verify Warrington and Shallice's position regarding the role of sensory attributes in category specific deficit for living things. Therefore, the semantic knowledge of this novel category, comprising different types of stimuli which can be generally ascribed to the class of "mass" kinds was examined. Actually, the presence of deficits affecting both living things and the category of foods, which should rely on a processing mostly based on sensory analysis, have been described in the literature, but Warrington and Shallice's predictions have never been investigated more thoroughly through the employment of other "sensory quality" categories different from foods.

Therefore, two categories, liquids and materials, in addition to three frequently investigated, namely, man-made artefacts, living things and edible substances were hence assessed in the present work. A primary purpose of this study was addressed to the fine-grained investigation of the plausibility of the close relation between living things and different types of "mass" kinds, which, as predicted by Warrington and Shallice (1984), should rely on the same sensory processing. Patients' semantic knowledge of three semantic domains —man-made artefacts, living things and "mass" kinds— was therefore probed in the first three experimental sections (5.3, 5.4 and 5.5). The examination of the semantic system was then performed with respect to patients' categorical knowledge and, in parallel, from a featural perspective. Categorical knowledge generally refers to patients' ability to deal with tasks widely used in category specificity studies, such as naming, matching, categorisation and sorting tasks, which assess various aspects of semantic skills through different modalities of stimuli presentation. However, the adoption of tasks aimed at investigating patients' knowledge of semantic properties of the stimuli, and not merely that associated to the broad knowledge of categories, allows both Warrington and Shallice and Caramazza and Shelton's predictions to be tested. In fact, the first authors hypothesise a differential impairment of the two types of semantic attributes, such as sensory and functional information, in patients with a category specific deficits for living things, whereas in Caramazza and Shelton's view no difference should be observed in patients' featural knowledge, but only a clear-cut categorical deficit. However, the undoubtedly large series of reports of deficits affecting the knowledge of concept attributes described in the category specificity literature (section 3.2) suggests that these "categorical" effects might be attributed to some extent to an intact or disrupted "featural" knowledge. More specifically, as predicted by Warrington and Shallice, sensory and functional attributes of concepts might be differentially involved in the semantic processing of the main domains of living things, man-made artefacts and the novel "mass" category. Therefore, an assessment of patients' featural knowledge paralleled that of "categorical" knowledge, through a series of tasks, such as naming after verbal definitions, questionnaires, semantic attribute production and judgement of features, all stressing either sensory or functional properties of concepts.

However, several studies have addressed the purpose of differentiating functional vs. sensory knowledge in patients with category specific deficits (sections 3.2.1 and 3.2.2) but a real attempt at adopting narrow but well circumscribed definitions of these concepts has yet to be achieved. However, the confusion arisen from an unrefined use of such terms both in previous and, to some extent, also in the present work, may obscure some relevant effects in patients' performance.

Four subsequent experimental sections were devised in order to achieve a better understanding of the category specific deficit for living things showed only by MU, one of the HSE patients who entered this study: the first one (section 5.3) attempted to broadly define, through a limited but well controlled series of tasks, MU's category specific deficit. The second one (section 5.4), strictly associated to the first, aimed at confirming MU's deficit through the adoption of a larger set of tasks, in order to achieve a basic but well comprehensive framework of the patient's semantic memory problem. The subsequent experimental section (5.5) addressed more specifically his knowledge of semantic properties associated to the preserved and impaired categories described in the previous two empirical investigations. At variance, the last investigation (section 5.6) addressed from an experimental perspective some issues which did not receive in the past literature sufficient attention. In fact, as shown in the previous experimental sections, some inconsistencies were observed in MU's performance over tasks and were supposedly imputable to discrepancies in the definition of notions such as "functional" and "sensory" information types. Therefore, a preliminary effort aimed at disentangling and segregating different aspects associated to these notions was performed. However, even though some hints came from this last experimental section (5.6), the assessment of patient MU only, without the control provided by the comparison of his performance to that of other patients or, at least, normal subjects, and the use of not widely controlled sets of stimuli, allows only some provisional suggestions to be put forward. Anyway, the importance of a more strict definition of these notions is stressed by the preliminary findings described in this final section.

6.2 MU's category specific deficit for living things

As reported in the first experimental part (5.3), patient MU showed a strong and highly significant advantage for man-made artefacts, that were correctly recognised about 50% better than living things in a task of naming on visual confrontation (section 5.3.1.1), even though all the stimuli used in the naming task were strictly balanced for the critical variables outlined in previous studies (section 3.3.2). Critically, the other four patients provide a valuable control group, as they had naming problems and were held to have suffered from the same disease process. Moreover, their mean performance on man-made artefacts was virtually identical to that of MU. Thus in the naming task MU's performance was strictly comparable to that of the patient controls with man-made artefacts items (see table 7), but his performance differed significantly from the patient controls when stimuli belonged to the living things class. Therefore, one patient, MU, differed from the mean performance of the group of the other four in having a very marked category specific effect selectively sparing man-made artefacts of the sort previously described (Warrington and Shallice, 1984; De Renzi and Lucchelli, 1994; Laiacona et al., 1997). The same category specific advantage for man-made artefacts was again observed in MU when compared to patient controls in the case of functional and sensory verbal description naming (tables 10 and 7), in contrast with a very poor performance with respect to living things (section 5.3.1.2 for both types of descriptions). On a similar ground, MU's performance in two matching tasks (section 5.3.1.4) was highly impaired in comparison with patient controls as far as living things were considered, whereas he showed an almost intact performance with man-made artefacts, with no difference as regards the patient control group on the same two tasks (see table 7). Then two questionnaires (section 5.3.1.3) tapping patients' knowledge of functional and sensory properties of living things and man-made artefacts were administered to the whole group of patients. As shown before, MU's ability to deal with man-made artefacts concepts was equal to that of patient controls both when functional and sensory attributes were examined (tables 11, 12 and 7). In contrast, a significant difference between his performance and that of patient controls arose when living things were taken into account, both with functional and sensory questions (see figure 6). However, there is one other aspect of the naming impairment for living things observed in MU in the first experimental section (5.3). When coloured stimuli were used of much better quality than the standard Snodgrass and Vanderwart pictures the basic artefact-to-living things observation remained. This corroborated the basic findings of Warrington and Shallice (1984) on their critical patients. However rather contrasting results have been obtained by Moore and Price (1999) in functional imaging studies of category specific effects in normal subjects (section 3.4.2). In contrast to earlier functional imaging studies they used two pairs of categories for living things (animals, fruits) and artefacts (vehicles, tools) which were orthogonally contrasted on degree of structural complexity. Tasks involving the living things categories activated more the anterior temporal cortex bilaterally and the right posterior middle temporal cortex. The two anterior temporal sites fitted with MU's lesion site. However the category specific effect in Moore and Price's study disappeared when coloured stimuli were used, particularly in the right hemisphere areas. The imaging and lesion results are therefore not completely compatible in MU's case.

On the same lines are the data described in the second experimental section (5.4): MU's damage concerning the living things class was again constant over the majority of tasks comprised in the battery used (5.4.2); quite the reverse pattern was found in the case of man-made artefacts, where a strikingly similar performance characterised his scores and those of the group of patient controls as well. In a visual confrontation naming task (section 5.4.2.1) MU was extremely poor with living things, while spared in the case of man-made artefacts (table 15). Patient controls instead were shown to be quite similar with both categories. The same trend was observed both in verbal definition naming (section 5.4.2.2) after functional and sensory descriptions (tables 16 and 18). A significant difference between MU and patient controls was found also in a categorisation (section 5.4.2.3), where MU was defective as regards living things, being, in contrast, equal to patient controls in the case of artefacts (table 19). A word-to-picture matching task (5.4.2.5) was also administered to patients in the second experimental section. Again MU's advantage for man-made artefacts was found with respect to living things when his performance was compared to that of the patient control group (table 21). MU's category specific deficit for living things was therefore found in every task of the battery, with the exceptions of the highest level of discrimination of the sorting task (table 20, section 5.4.2.4), where both living things and artefacts were shown to be impaired, although the latter case might be explained on the light of very high task demands.

An amelioration with respect to the tasks used in the first experimental investigation was the choice to take into account possible discrepancies in patients' performance with respect to subclasses of stimuli belonging to the main domains of living things and man-made artefacts. As shown in table 22 (section 5.4.3), land animals and birds were the subcategories more frequently impaired within the living things class, while fruits and vegetables led only occasionally to disruption; at variance, household and vehicles were found to be generally spared in patient MU's performance over the same array of tasks of the battery. The employment of subcategories is relevant because case reports have been described in which a deficit was sometimes well restricted to a selective subclass of the living things domain (section 3.2).

6.3 MU's selective deficit for "mass" kinds

However, the most striking data come from the visual confrontation naming task administered in the first experimental section (5.3), in which five semantic categories, living things, man-made artefacts, edible substances, liquids and materials, were examined. Patients' performance was quite variable in naming (section 5.3.1.1, table 7) different types of "mass" items, but MU presented with a severe deficit with respect to all the new categories when compared to patient controls. The assessment of "mass" knowledge through a questionnaire emphasising functional or sensory attributes of the stimuli (section 5.3.1.3), revealed the usual trend for patient MU in contrast to patient controls (figure 6). Both functional and sensory knowledge of "mass" kinds was defective in MU when compared to patient controls over two (substances and materials) of the three classes of stimuli, with the only exception of liquids in the case of functional attributes and where the critical patient was not different from the patients group, whereas a trend toward a deficit was observed in the case of sensory properties of liquids (table 7). However, apart from the report of a clear impairment affecting MU's knowledge of both living things and different classes of "mass", if one examines the "mass" categories and the most basic sensory quality domain of "living things" in the visual confrontation naming task (section 5.3.1.1, figure 5), the performance of the whole group of patients is shown to be remarkably parallel across the four conditions (living things, liquids, materials and substances). Although there was a trend for naming substances to follow a slightly different pattern across patients, this was not significant. In contrast, man-made artefacts followed a very different pattern from that of the other four categories in the same task (figure 8). Allowing for minor discrepancies in difficulty across the four types of stimuli, living things, substances, liquids and materials, a difference across patients on a single factor would explain the pattern of results (see figure 5).

In the second experimental section (5.4), MU's knowledge of "mass" kinds was further examined through a larger number of tasks with respect to the original report of his deficit described in section 5.3. This would allow a better assessment of the patient's knowledge related to "mass" stimuli. The utilisation of three categories of "mass", such as edible substances, liquids and various materials was motivated by the use of the same classes in the first experimental section (5.3). Unfortunately, this basic battery for the assessment of "mass" knowledge (section 5.4.4) could not be administered to the patient controls group but to a group of normal subjects. However, considering just MU's results, the patient showed such a generalised and severe deficit, affecting about to the same extent three categories, edible substances, liquids and materials, that these data provide substantial support to the findings presented in the first experimental section (5.3) as respect to "mass" kinds. MU was severely impaired in a visual confrontation naming task (section 5.4.4.1, table 26) with all substances, liquids and materials. Moreover, the same deficit for "mass" stimuli was observed in MU's performance in three matching tasks (5.4.4.2), an inter-categorical matching with 8 alternatives and highly similar distractors (table 27), an inter-categorical matching task with 4 alternatives and highly similar distractors (table 28) and in an extra-categorical matching task with 8 alternatives and visually similar distractors (table 30). The patient showed a dramatically poor performance also in a harder version of a sorting task (table 32). Although showing a somehow improved performance, MU was also defective in an extra-categorical matching with 4 alternatives and visually dissimilar distractors (table 29) and was comparable to controls in the easiest version of the two sorting tasks administered (table 31), being affected only with materials subclass. In general, no relevant differences were found as respects to the three subcategories, leading to the possibility of the influence of a unique underlying semantic processing for these classes. Therefore, a comparable pattern of performance was found in patient MU both in the first (5.3) and second (5.4.2 and 5.4.4) experimental sections when presented with stimuli pertaining to the living things domain and different classes of "mass" kinds. The findings related to the second assessment of patient MU's knowledge of "mass" (5.4.4), much more wide-ranging with respect to those of previous investigation (5.3), seem to provide support to the hypothesis of a close relation between these two semantic domains, which might perhaps rely on the same underlying semantic processing. Furthermore, the influence of relevant factors in MU's naming performance both with respect to living things (5.4.2.1) and "mass" stimuli (5.4.4.1) was not observed. The effects found for the newly investigated categories and the classical domain of living things therefore directly support the contrast between sensory quality-function based categories, as observed in the initial account of the syndrome (Warrington and Shallice, 1984).

6.4 MU's semantic featural knowledge

6.4.1 Semantic attribute production

However, the assessment of the category specific deficit shown by patient MU was also pursued through the adoption of a featural perspective. The importance of evaluating the knowledge of semantic attributes is critical to test the hypothesis of both authors who suppose that these underlie the representation of different concepts in the semantic system (Warrington and Shallice, 1984) and also that of authors who predict that featural knowledge is not fundamental in category specific deficits (Caramazza and Shelton, 1998). Therefore, a wide-ranging assessment of MU's semantic featural knowledge of living things, "mass" kinds and man-made artefacts was carried out in the third experimental section (5.5). Two different types of tasks, both about living things and man-made artefacts on the one hand, and "mass" kinds on the other, were devised with this purpose, a semantic attribute generation task (sections 5.5.2 and 5.5.4) and a feature verification paradigm (sections 5.5.6 and 5.5.8), reflecting the idea (Warrington and Shallice, 1984) that the organisation of the semantic system might be conceived in terms of differential processing of concepts, relying preferentially on functional information, in the case of man-made artefacts, and on sensory features, as far as "sensory-quality" categories such as living things and "mass" stimuli, are concerned.

In the semantic attributes generation task of living things/man-made artefacts (section 5.5.2) and "mass" kinds (section 5.5.4), patient MU had a control group HSE patients in the case of living things and man-made artefacts, and normal subjects in relation to "mass" stimuli.

MU was comparable to controls in providing category information, about living things (table 35); the same pattern of preservation was observed also in the case of animals (table 7, appendix A) and birds (table 8, appendix A), while he was better than patient controls as respect to fruits and vegetables. MU showed a good performance also with man-made artefacts (table 36) and with the subcategories of tools (table 11 appendix A) and vehicles (table 12, appendix A), showing however an impaired category knowledge in the case of households (table 10, appendix A). The same behaviour was observed in MU's performance as regards to liquids (table 42) and materials (table 43), with the only exception of category knowledge of substances (table 41).

MU was also equal to controls in the production of *encyclopaedic* properties of living things (table 35) and man-made artefacts (table 36), being comparable to the mean performance of patient controls with respect to all living and non living subcategories (tables from 7 to 12, appendix A). Patient MU showed also a good performance as respect to encyclopaedic information of substances (table 41) and liquids (table 42), being even significantly better than normal controls in the case of materials (table 43). In the case of functional information he was equal to HSE controls with artefacts (table 36), household items (table 10, appendix A) and tools (table 11, appendix A), and he could provide significantly more information as respect to vehicles (table 12, appendix A). MU was significantly better than the patient group with living things (table 35) and, more specifically, in the case of animals (table 7, appendix A) and fruits and vegetables (table 9, appendix A), being instead comparable to the patient group in the case of birds (table 8, appendix A). As far as the three classes of mass kinds were concerned, MU was not different from normal subjects with liquids (table 42) and materials (table 43), and showed a better performance than controls with respect to substances (table 41).

However, his production of *sensory* information about living things, though very poor, was not significantly different from the mean performance of patient controls (table 35). In fact he was equal to the patient group in the case of animals (table 7, appendix A), birds (table 8, appendix A) and fruits and vegetables (table 9, appendix A). However, it has to be stressed that, at least with animals and birds, MU's performance was very poor and the absence of a significant difference from HSE controls was due to insensitivity of the task, being the patient group's performance highly variable, therefore preventing an otherwise clear deficit to arise with statistical significance. However, the patient was highly defective in the case of both man-made artefacts category (table 36) and the three related subcategories (tables 10, 11 and 12, appendix A). Furthermore, the same dramatic impairment was observed for all three subcategories of the "mass" domain (tables 41, 42, and 43). It should be observed, therefore, that MU's production of semantic features related to sensory knowledge was constantly poorer in comparison to that of functional features. This trend was evident as respects to both living things, man-made artefacts, and the "mass" category.

These findings provide a substantial support to Warrington and Shallice (1984) and Farah and McClelland (1991) position: the presence in patient MU of a severe deficit in supplying sensory properties relative to functional information is reported for each of three semantic domains: living things, man-made artefacts and "mass" kinds. As predicted by these authors, a category specific deficit relative to living things, and, in the present study, also to "mass" stimuli, should be due to damage of sensory-quality processing within the semantic system, a loss that should affect in a cross-categorical fashion the semantic domains of living things, "mass" stimuli and also man-made artefacts, although to a lesser extent in the latter case (Farah and McClelland, 1991). However, the deficit involving sensory-quality knowledge affects the three semantic domains to the same extent, although in Warrington and Shallice's account, and in Farah and McClelland (1991) computational model, the impairment of sensory attributes of man-made artefacts should be less prominent than that of living things and "mass" stimuli, being man-made artefacts supported by functional properties to a greater extent with respect to living things and "mass" categories. Anyway, the present findings do not present this differential pattern of impairment of sensory knowledge in the two main domains, being both equally defective.

6.4.2 Semantic attribute verification

However, the results obtained from two features verification tasks about living things and man-made artefacts (section 5.5.6), on the one hand, and "mass" kinds (section 5.5.8) on the other, lead to a less straightforward interpretation. This tasks allow a detailed analysis of various key dimensions: a segregation over domains; a direct evaluation in terms of subcategories belonging to the main domains; an examination based on the relative distinctiveness of semantic featural properties; a direct comparison of different types of semantic information, such as category, encyclopaedic, functional and sensory properties.

Firstly the knowledge of two general semantic domains, living things and man-made artefacts, and their subcategories was examined (section 5.5.6). MU's comparison to patient controls in this task puts in evidence in the critical patient a dissociation characterised by an highly selective deficit involving only the living things domain (table 47) and its related subcategories of animals, birds and fruits-vegetables (table 13, appendix A). At variance, MU's semantics of man-made artefacts (table 47) and relative subclasses of household items, tools and vehicles (table 13, appendix A) appears to be intact. Furthermore, the examination of MU's feature knowledge associated to the main categories of living things reveals a deficit involving every type of semantic information held to define this semantic domain. In fact, all types of information related to living things, such as category (table 49), encyclopaedic (table 51), functional (table 53) and sensory (table 55) properties were shown to be damaged in patient MU in comparison to patient controls. The generalised impairment related to all types of semantic information is also found for animals and fruits and vegetables, as shown in appendix A, in tables 14 for category, 15 for encyclopaedic and 17 for sensory information. It should however be noted that functional knowledge of birds (table 16, appendix A) was found to be preserved in MU, while he showed the usual deficit in the case of animals in comparison to patient controls.

In sharp contrast, MU's featural knowledge of the main class of man-made artefacts was found to be flawless and equivalent to that shown by patient controls in the case of category (table 49), encyclopaedic (table 51), functional (table 53) and sensory (table 55) attributes. Similarly, MU's knowledge of semantic properties of subclasses pertaining to the man-made artefacts domain, such as household utensils, tools and vehicles was found to be unimpaired when compared to patient controls for all information types (tables 14, 15, 16 and 17, appendix A).

Another theoretically important dimension of semantic knowledge, as the distinctiveness of semantic features, was also analysed in the case of all types of semantic information (tables 50, 52, 54, 56 and 57), being both distinctive and shared properties damaged with respect to patient controls as far as the living things domain and associated subclasses were concerned. In contrast, the sparing of MU's knowledge of both distinctive and shared information of man-made artefacts and their subcategories was observed for all types of semantic features (tables 50, 52, 54, 56 and 58).

However, it has to be observed that considering MU's performance alone, the patient was much more able to judge functional rather than sensory properties of both living things and man-made artefacts. This result seems therefore consistent with the findings described as regards to the semantic attribute generation task for living things and artefacts (section 5.5.2). However, from a more general perspective, these findings (section 5.5.6) neatly parallel previously described results from the whole array of tasks presented in the first (5.3) and second (5.4) experimental investigations, and provide further support, by means of a quite different and articulated task, to the reliability of the category specific deficit limited to living things shown by MU. However, no signs of a differential deficit affecting sensory as respect to functional knowledge is shown by the findings of this first feature verification task (5.5.6). MU's featural knowledge is damaged as a whole when living things are considered, whereas being intact in the case of man-made artefacts. This last result is therefore not predicted by Warrington and Shallice's (1984) view about the role played by sensory processing in determining a specific deficit for living things. Even though the deficit for living things clearly emerges from MU's performance on this task, it is not paralleled by a widespread deficit to sensory with respect to functional knowledge. Therefore, if one considers only the data regarding living things and man-made artefacts in patient MU, the findings described in sections 5.3, 5.4 and 5.5.6 seem to provide support to Caramazza and Shelton's (1998) view of a deficit damaging *in toto* a singular semantic domain, living things, leaving spared the knowledge associated to the opposite domain, man-made artefacts. Moreover, the assumption of no role of differential featural processing in giving rise to category specific deficit, as proposed also in Caramazza and colleagues OUCH model, seems to be confirmed by the data from the features verification task about living things and artefacts.

However, a quite contrasting picture arises from the feature verification task about "mass" kinds (section 5.5.8). MU's general knowledge of "mass" stimuli was highly disrupted with respect to substances, liquids and materials (table 62) and their subclasses (table 18, appendix A), as also observed in the first two experimental sections (5.3 and 5.4) through the use of quite different tasks. Moreover, when asked to verify statements about different types of semantic information MU was completely unable, in comparison to normal controls, to judge category membership about substances, liquids and materials (table 63), with the only exception of subcategories of foods and non-alcoholic drinks. A widespread impairment was also observed as far as encyclopaedic, functional and sensory information were taken into consideration, and MU's deficit comprised all the three categories and subcategories of "mass" stimuli. However, it is worth noting that despite the patient general deficit, when compared to normal subjects, MU's individual performance was still better in judging functional relative to sensory properties about "mass" kinds, as was also described in the previous feature verification task regarding living things and man-made artefacts (section 5.5.6), and it is also consistent with the data presented as regards the attribute generation task for "mass" stimuli presented in section 5.5.4.

This last series of results (section 5.5.8) is in keeping with previous investigations of MU's knowledge of different kinds of "mass" (sections 5.3 and 5.4), showing in addition a deficit in providing correct judgements about sensory features with respect to functional information, as was also described with reference to the attribute generation tasks implying "mass" (5.5.4) and living things and man-made artefacts (5.5.2). At variance with the general findings from the feature verification task about living things and man-made artefacts (5.5.6) —although MU's individual performance with functional features was however different from that related to sensory attributes—, an interpretation in terms of the sensory quality/functional distinction originally proposed by Warrington and Shallice (1984) is once more suggested.

6.5 Comments on the first three experimental sections

In the seminal work of Warrington and Shallice (1984) the differential weighting of certain types of semantic properties was suggested as basic for the understanding of category specific deficits: for living things sensory-quality properties are the most salient features for the discrimination of different exemplars of this semantic category. On the contrary, the semantic representation of man-made artefacts is much more dependent on attributes designing their function. A damage to the sensory properties would then affect to a greater extent the living things category, leaving instead relatively unaffected man-made artefacts. This theoretical account, also modelled by Farah and McClelland (1991), has received substantial support from a large series of studies on category specificity effects. Patients with a selective deficit for living things showed the predicted pattern of disruption of sensory information, with respect to non-sensory properties (De Renzi and Lucchelli, 1994; Farah, Hammond, Metha and Ratcliff, 1989; Hart and Gordon, 1992; Sartori and Job, 1988; Sartori et al., 1993a; Sartori et al., 1993b; Silveri and Gainotti, 1988; Powell and Davidoff, 1995). Therefore, a damage to sensory properties should lead to a cross-domain disruption, which brings as a primary consequence a wide impairment of the knowledge of the living things category. Moreover, this deficit should imply also an involvement of sensory properties knowledge of other categories as well, such man-made artefacts (Farah and McClelland, 1991). In this latter case, the damage to the category should be less severe, insofar as man-made artefacts representation relies prominently on other types of semantic information, such as functional attributes.

However, in recent times an increasing number of studies reported quite different patterns of impairment, in contrast with the predictions following from Warrington and Shallice's (1984) account. For example, Laws et al. (1995) described the case of an HSE patient whose knowledge of visual-sensory properties of animals was relatively preserved, showing instead a selective deficit for their associative and functional information. Although this pattern of findings was not replicated in a subsequent study by Moss, Tyler and Jennings (1997) on the same patient, an increasing number of studies report cases of patients with category specific deficits for living things who do not present a cross-categorical impairment to visual-sensory features (see sections 3.2.1 and 3.2.2). For example, in the Moss et al.'s (1997) study, the authors observed that a patient had a mild category specific deficit for living things, with the predicted relative disruption of their visual properties, but patient's knowledge of visual attributes of non living stimuli was unaffected. In other cases, patients who do not show a category specific impairment for living things present selective difficulties in the processing of visual semantic features (Lambon-Ralph et al., 1998).

6.5.1 MU's category specific deficit for living things and "mass" kinds

The discrepancy between living things and man-made artefacts found in patient MU and described throughout this work are difficult to explain on alternative "artefactual" accounts. Thus explanations which relate the presence of the category specific effect to a particularly severe level of impairment (e.g. Gonnerman et al., 1997) do not work. The patient controls who were matched to MU on naming performance with man-made artefacts showed only a minor category specific effect (patient BAR in experimental part 5.3). Moreover, other patients who were worse than MU on the man-made artefacts items were slightly better than him on the living things category (patient MIO, section 5.3), quite contrary to the Gonnerman et al.'s (1997) position. The slight superiority of the control patients on man-made artefacts can be explained, on the Gaffan and Heywood's (1993) position concerning the densities of exemplars within the category, even though they were matched on all the standard variables. However, being MU's problem significantly greater than that of controls, it might involve a separate factor and would therefore appear <u>not</u> to be explicable on the Gaffan and Heywood's position. The advantage for man-made artefacts found in MU can therefore be attributed to a genuine category specific effect: plausible alternative accounts do not seem to be able to explain the data. Not only were the stimulus sets carefully matched for dimensions considered of essential importance, such as word frequency, visual complexity and concept familiarity, most critically his performance is qualitatively quite different from that of a control group of HSE patients (sections 5.3 and 5.4).

A second reason why the attempts to explain away the category specific findings in herpes encephalitic patients as the effect of background variables relating to quantitative aspects of categories (e.g. Gaffan and

Heywood) or stimulus variables (e.g. familiarity, stimulus implications) are difficult to maintain for MU, is that the effect extends to three categories (sections 5.3.1.1, 5.3.1.3 and 5.4.4), namely edible substances, liquids and materials, two of which have no overlap with categories previously held to be critical (living things and foods). As outlined in the first experimental investigation (section 5.3.1.1), the patients as a whole showed a very neat parallel performance over these two categories and living things (figure 5) which indicates that a common factor was responsible for their behaviour. Most critically, MU performed very poorly indeed with "mass" kinds both in the first (5.3) and second (5.4) experimental investigations —and no effect of relevant factors was reported to influence the patient's behaviour in visual confrontation naming tasks—, and also in the attribute generation (section 5.5.4) and the feature verification tasks about "mass" stimuli (section 5.5.8). Yet the three "mass" categories must differ greatly from living things on the background variables.

This result provides strong evidence in favour of the Warrington and Shallice (1984) hypothesis that some dimension of the stimuli related to the sensory quality/functional distinction is fundamental in the semantic processing of living things and man-made artefacts by herpes patients. Sensory qualities (such as colour and texture) are essential when differentiating living things, which generally have no function and are not manipulable. They are even more critical, for other types of stimuli where shape is <u>not</u> a distinguishing factor (materials, substances, liquids etc.). Therefore, MU's performance over the full array of tasks involving living things, "mass" kinds and man-made artefacts seems to reflect the relative weight of either sensory and non-sensory aspects of meaning in the course of semantic processing. In MU's case the presumed disruption of the ability to represent sensory quality features has led to a severely defective performance with materials, edible substances and liquids, as well as with living things, leaving instead relatively intact his ability to process man-made artefacts, held to be based mainly on function processing. Moreover, the way that the dissociation is reflected in other types of task, e.g. ones with auditory-verbal input, indicates that the effect is not merely an early visual perceptual impairment. De Renzi and Lucchelli's (1994) position on the importance of the form-function links for man-made artefacts would also predict these results.

In fact, living things and "mass" kinds can be discriminated in terms of sensory-quality semantic properties, but the large majority of exemplars pertaining to the living things domain do not straightforwardly imply any distinctive function, while this is a general characteristic of man-made artefacts. The knowledge of what a given animal can do, or what it might be used for, are not notions which distinctively define and represent a member of the living things class. "Mass" stimuli, similarly to living things, are not directly linked to a highly specific functional context, being employed for a large variety of uses and being also manipulated in very different manners. These considerations make them much more similar to living things, rather than man-made artefacts. The lack of functional specification which characterises living things and "mass" items on the one hand, and the peculiar role sensory-quality features play in concept representation on the other hand, provide a theoretical support to the interpretation of the above findings in terms of a similar (or identical?) semantic processing to which both classes of stimuli might undergo.

Therefore, the results obtained in the first experimental section (5.3), from two batteries (5.4.2 and 5.4.4) and two attribute generation tasks assessing the semantic knowledge of living things, man-made artefacts (5.5.2) and "mass" stimuli (5.5.4), and finally, from the two feature verification tasks —provided that MU's performance is considered singularly—, confirm the presence in patient MU of a deficit for living things and "mass" kinds that affects the large majority of tasks both in visual and verbal modalities, in contrast to an advantage for man-made artefacts.

6.5.2 Considering the findings from different theoretical perspectives

However, from a quite different point of view, that is, the evaluation of data examining MU's performance on the light of the functional/sensory distinction, a paradoxical phenomenon arises. Therefore, when MU's performance with living things and man-made artefacts was compared (see tables 7, 16 and table 2, appendix A), a highly significant deficit, restricted to living things, was observed in naming from verbal descriptions (sections 5.3.1.2 and 5.4.2.2), whereas the same pattern was not found in the case of patient controls. The same type of effect is found in his responses to questionnaires emphasising functional and sensory attributes of living things and man-made artefacts and "mass" stimuli (table 7, section 5.3.1.3), with the exception of liquids. On the same line, the findings described in the feature verification task for living things and man-made artefacts (section 5.5.6) follow in general the same behaviour of a dramatic categorical distinction between the two domains, with no effect of featural knowledge.

Thus, looking exclusively at the living/man-made artefact difference, MU shows a category specific effect that affects one class of objects —living things—, in a wide range of tasks but spares instead the contrasting category —man-made artefacts—. Therefore, from this series of results the position seems to be supported, of a clear-cut difference between two domains of knowledge, one spared after the damage and the other globally impaired, as put forward by Caramazza and Shelton (1998), instead of a difference in terms of differential processing required to analyse the two types of stimuli, one based upon sensory quality information and the other relying more upon the functional attributes of the input, as also proposed by Caramazza and co-workers in their OUCH model (Caramazza et al., 1990; Rapp et al., 1993; Hillis et al., 1995).

However, if one considers the remarkably parallel behaviour shown by MU in relation to the whole set of data related to living things and stimuli belonging to the "sensory-quality" categories of substances, liquids and materials —as described in the first (5.3) and second (5.4.2 and 5.4.4) experimental investigations, in the two attribute generation tasks (5.5.2 and 5.5.4) and in the feature verification task about "mass" (5.5.8)—, it should be clear as these findings are in conflict with an explanation in terms of the Caramazza and Shelton's (1998) theory, being much more easily accounted for on the basis of the Warrington and Shallice's (1984) view, that the critical patient has lost sensory quality information. As matter of facts, Caramazza and Shelton (1998) only consider the categorical distinction between living things/foods vs. man-made artefacts domains within the semantic memory system. However, the types of "mass" stimuli adopted in the present work do not comprehend only foods, but also other items, such as materials: these stimuli should not have any direct relation to the evolutionary pressures that, on Caramazza and Shelton's (1998) hypothesis, would have driven the organisation of the semantic memory system into two separated domains (living things/foods vs. man-made artefacts). For a more comprehensive understanding, two findings have to be highlighted: first, the similar behaviour of living things and the entire set of "mass" items, which are demonstrated to be severely damaged in patient MU (sections 5.3 and 5.4); second, MU's dissociation between functional (preserved) and sensory (impaired) attribute knowledge, clearly shown in the attribute generation tasks (sections 5.5.2 and 5.5.4), in the feature verification task for "mass" kinds (5.5.8), and, examining only MU's individual performance, also in the feature verification task about living things and man-made artefacts (section 5.5.6). Therefore, although the whole set of results from tasks implying the functional/sensory difference does not allow an unequivocal interpretation of the featural impairment and preservation of semantic attributes associated to living things, "mass" items and man-made artefacts, these findings cast nonetheless doubts on Caramazza and Shelton's (1998) theoretical view, which seems to exclude any possibility of a reliable reinterpretation or development of their theory, in order to possibly account for the main trend of results described here. The likelihood of a revision of some implications of the Warrington and Shallice's (1984) position seems instead easier to be performed.

6.5.3 An attempt to an exhaustive explanation of the findings

How can these rather contradictory set of findings be resolved? The computational model of semantic memory presented by Farah and McClelland (1991) seems to give, at least partially, an explanation of the finding that MU was impaired in the retrieval of both functional knowledge for living things as well as sensory quality information in tasks such as the two naming tasks from verbal description (sections 5.3.1.2 and 5.4.2.2), the two questionnaires (5.3.1.3) and finally the feature verification task about living things and man-made artefacts (5.5.6). Damage to the visual (sensory-quality) component of the computational model gives rise to a deficit in the retrieval of perceptual attributes of living things as well as to an impairment, although not equal in gravity, in the retrieval of their functional characteristics. On the model if the activation of a "critical mass" of units is necessary for a given representation to be accessed, then it would be possible that, after massive damage to one component (i.e. the visual), it is no longer able to access information stored in the relatively unimpaired component (i.e. functional) for a particular type of stimuli. This would be the case for categories which have much larger, in the sense of number of units activated, sensory quality than functional representations. When a large proportion of these units representing a given item are damaged, then the other units that are intact loose the collateral connections which are necessary for the information they represent to be satisfactorily accessed (see exp. 3 of Farah and McClelland, 1991). Categories which have these characteristics would have matched the traditional living things categories of animals and fruit/vegetables but also the "new" categories of liquids, substances and materials. In the case of the assumption of a larger sensory-quality than functional representation units, a modification should however be made: the use of a more restricted concept of function, than, say, that employed by Tyler and Moss (1997), is required to account for the results. In the case of the new categories, as well as in the case of artefacts, function should be related to manipulability or, in more general terms, to action-related information as in Buxbaum and Saffran's (1998) study. In Farah and McClelland's (1991) view, this modification would allow one to explain the overall pattern of the living/man-made artefact dissociation in terms of the sensory-functional hypothesis (Warrington and Shallice, 1984).

6.6 Further considerations on the sensory-quality vs. functional distinction

However, the possibility that the concept "function" has been used too abstractly is here acknowledged. The function of, say, scissors is linked to the action one uses on it; one sees the function being realised. Similarly when one sees a bus, one often sees its function being realised, in satisfying your or others' intentions, to travel from A to B. If, however, one considers a functional question concerning a cow, say "what drink is obtained from cows" the relation is much less concrete for most of us. We see cows when we walk through a field or see them from a car or train. However, there is no direct link to milk. Thus functional information relating to animals does not seem to be as concretely equivalent to functional information relating to artefacts, where, in addition, as De Renzi and Lucchelli (1994) point out, function is closely linked to form. Thus the representations of the functional aspects of living things may be much less concrete than for artefacts and so require greater computational support from their sensory-quality representations.

Therefore, if the concept "function" is interpreted as an abstraction of how objects are manipulable, as in the Buxbaum and Saffran's (1998) position, then the concept would need to be sharply differentiated from "encyclopaedic", "associative" or "contextual" information. Given the findings of McCarthy and Warrington (1988) it seems plausible that encyclopaedic information can be directly addressed from both visual and verbal semantic representations. Thus an additional deficit affecting this type of information could explain the results. This relates to the issue of what a functional information impairment relating to living things implies psychologically.

An objection to the functional vs. sensory-quality explanation is made by Lambon-Ralph et al. (1998). They described a patient, IW, with a semantic dementia. Their other patient, DB, with Alzheimer's disease, presents related phenomena to those described by De Renzi and Lucchelli (1994). However, IW was impaired at naming both artefacts and living things but showed no major differences between them. However on a number of tests she was worse at using perceptual than functional knowledge. The authors held that this should have led to her having greater difficulty with living things.

There is however a major problem in the interpretation of the two most critical tests used with IW. As a patient suffering from semantic dementia, IW had difficulty with lower frequency words, scoring for instance very poorly on the Shallice and McGill word-to-picture matching test, which was attributed to greater loss of knowledge of words than pictures (see McCarthy and Warrington, 1988; Lauro-Grotto et al., 1997 for related phenomena). Yet the primary test of perceptual knowledge involved many low frequency words such as "curl, saddle, pedal, trigger, prong, blade, lens, hilt, amber, buzz, antennae, hump, maiow, purr, crow" etc. Secondly the authors report that IW refers to more associative than perceptual features in defining objects and living things. However again, there is no discussion of any possible role of word frequency. Moreover, she produces very little information at all —an average of 1.4 features per presented item. Also no examples and details are given about what she does produce, so it is impossible to judge whether use of superordinate information or a familiarity bias could have affected the findings. Thus neither critique of the sensory quality/function distinction is convincing.

In the light of the criticisms to which Lambon-Ralph et al.'s (1998) study is subjected, and taking into account the suggestions put forward by Buxbaum and Saffran (1998), new hints about the way "function" should be reinterpreted are proposed in this study.

Although the experimental and theoretical investigation of semantic information concerning category membership received initially a considerable attention, an increasing amount of reflection was devoted particularly to functional and sensory properties of concepts. Already in early accounts of category specific deficits for living things the selective damage of sensory attributes of both living things and artefacts was described along the categorical impairment (De Renzi and Lucchelli, 1994; Farah, Hammond, Metha and Ratcliff, 1989; Hart and Gordon, 1992; Sartori and Job, 1988; Sartori et al., 1993a; Sartori et al., 1993b; Silveri and Gainotti, 1988; Powell and Davidoff, 1995). However, some studies of patients with classical category specific deficit reported that semantic attribute knowledge was equally impaired as respects to functional and sensory properties (Barbarotto et al., 1995; Lambon-Ralph et al., 1998).

These last findings seem to reflect those describing MU's performance on two verbal descriptions naming tasks (5.3.1.2 and 5.4.2.2), two questionnaires (5.3.1.3) and the feature verification task for living things and artefacts (5.5.6) in the present work. However, as pointed out above, it might be likely that the type of functional information provided to patient MU was not precisely defined and circumscribed.

In the classical view, the notion of functional properties has been adopted with a huge variety of different meanings: the notion connected to the use of an object has been confused with information relative to the associative context, general encyclopaedic knowledge, properties related to action. The lack of a clear definition of what is intended by using the term function, leads to a major difficulty in the interpretation of findings previously described in the literature and in the authenticity of their related theoretical accounts. In the first theoretical account of category specific deficits relative to living things, Warrington and Shallice's (1984) held that an analysis in terms of function has a relatively fundamental role in the identification of man-made artefacts. Moreover, the fact that the notion of function might have different implications as regards man-made artefacts and living things categories was argued also by Tyler and colleagues (Tyler and Moss,1997; Tyler et al., in press) and De Renzi and Lucchelli (1994).

In De Renzi and Lucchelli's (1994) view, a crucial difference between the semantic representation of the living things and the man-made artefacts is not based on the greater proportion of visual properties with respect to non-visual ones characterising living things at variance to artefacts. Their principal difference, they argue, lies in the strength of the interconnections among visual and non-visual properties, which is claimed to be stronger in the case of artefacts. Information about the shape of a man-made artefact is closely linked to the function for which objects were designed. Thus, in the authors' view visual properties, the shape in the case of man-made artefacts, are dependent on non-visual properties, such as the function of objects. Only man-made artefacts are characterised by a tight relation between their form and their related function: in fact, the shape given to an object corresponds directly to the task in which the object has to be employed. In contrast, the shape of an animal does not suggest any peculiar function for which it can be used by man. What a hen has been made for? Its form does not suggest straightforwardly any way the animal could be used for by man. The fact that the hen provides eggs is by no means suggested by its shape. But an axe, composed by a handle and a heavy sharpened blade, suggests the purpose for which it is made, that is cutting. Its shape was built in that peculiar way just because it has to be used by man's hands for that peculiar purpose. The direct implication of this position is that a damage to the visual properties within the semantic system may affect only marginally the representation of man-made artefacts: the lack of definition due to the loss of visual properties can be overcame for objects by inferences from the related functional properties, while this cannot be the case for living entities.

However, an objection can be put forward with respect to De Renzi and Lucchelli's (1994) position. The shape characterising an artefact is held to be linked to its function, but form-function relation directly implies its function/use or is instead closely linked to manipulability? In the line with the suggestions proposed by Buxbaum and Saffran (1998) one could infer the function of an object not through its shape, but, indirectly, relying on information related to the pattern of actions involved in the manipulation of the object itself.

The first evidence of the possible role of the notion of manipulability was reported by Warrington and McCarthy (1987). The authors described a patient, with a category specific deficit for man-made artefacts, who demonstrated a selective difficulty with small manipulable objects relative to large man-made objects. This finding was accounted from a developmental perspective in terms of the differential role played by visual and sensory/motor channels within the acquisition and organisation of categorical knowledge.

The influence sensory/motor representations may have in object recognition is also stressed by Magnié et al. (1999), although no specific claims are made as respect to "function". Referring to Goodale and Milner's (1992) idea that two separate but interacting systems, the dorsal pathway —providing action-relevant information not only about position, but also about structural characteristics and orientation of objects— and the ventral system —seemingly involved in the production of functional properties of actions—, might play a role in visual recognition, the authors describe the case of a patient, JMC, who presented a recognition deficit limited to living things, while man-made artefacts were generally spared. However, his differential ability to recognise objects where he was able to produce the appropriate actions led the authors to suggest that a critical role in their patient's performance might be played by the spared knowledge he has about the actions (manipulability information) evoked by certain kinds of objects. JMC preserved ability should rely on the integrity of his occipital-parietal system. Magnié and co-workers suggest therefore that preserved processing of "how" to manipulate an object might account for the patients' ability to recognise the same objects.

Among the field of studies of object semantics, Buxbaum and Saffran (1998) put forward only recently a clear-cut distinction between "real" object function, such as what can be done with an artefact, and the notion of "affordance", meaning the action an object suggest. In their study of aphasic patients with apraxia the comparison of equally manipulable objects (i.e. piano, type-writer) was found to be a much more demanding task than when objects with similar function (i.e. radio, record player) had to be contrasted by patients. These data are the first account of a possible dissociation involving two close types of semantic knowledge: "real function" and manipulability. Therefore, following Buxbaum and Saffran the mode of manipulation of an object is clearly integrally linked to object shape and may well be the most critical element in the more global concept "function" held to be preserved in herpes encephalitic patients by Warrington and Shallice (1984) and in the present case as well.

6.6.1 Further examination of MU's featural knowledge

In the first three experimental sections of this work the term "function" was uniquely referred to the "use" an object suggests, thus clearing up this information from other more generalised semantic properties concurring to the definition of a concept. However, the emergence of some incongruities in MU's behaviour, when faced to functional information led to the idea that perhaps the functional information provided to him, especially in the feature verification task about living things and man-made artefacts (section 5.5.6), were <u>not</u> as "pure" as expected. The observation that MU's good performance with respect to functional feature verification related to living things was mainly explainable by the fact that the information provided included "action" notions much more than "use" notions (section 5.5.10), made clear the necessity of a further clarification about the "functional" notion.

6.6.1.1 Animals, function and action

On this ground, a redefinition of the possible multiple levels characterising the "sensory" notion seems to be needed if one considers the data discussed in the present work.

In recent times patients' knowledge of sensory properties was held to be connected to their degree of distinctiveness (Moss and Tyler, 1997; Tyler et al., in press): widespread sensory attributes —characterising the large majority of exemplars of a category—, should be more preserved after brain damage, at variance with specific sensory properties —which should be implied in the distinction of members of a given class—, and are held to be more prone to brain damage, leading to the occurrence of category specific deficit for living things (Tyler et al., in press). In the authors' view the classical sensory and functional concepts are reinterpreted in terms of form-function relations: as far as living things are concerned, highly shared sensory features are associated to their biological relevance (biological functions), such as eating or breathing, and are held to be preserved also in patients showing the classical category specific deficit for living things.

In contrast to this position, the suggested pattern of preservation of shared sensory features as respects to distinctive ones has not been replicated when MU's performance was compared to that of patient controls on the feature verification task regarding living things (section 5.5.6, table 56): in fact, both types of sensory information were damaged as respects to the category of living things, being instead both equally unaffected in the case of man-made artefacts (table 56). Moreover, no dissociation was found for distinctive vs. shared functional properties of living things, which, at least in the case of shared properties, should be intact after a category specific deficit for living things (table 54). However, in this task MU's performance was evaluated with respect to that of normal subjects and patient controls. Considering anyway his performance from a single case perspective, MU's knowledge of general (shared) sensory features, although mildly defective, was nonetheless twice as good as that related to specific sensory features (section 5.5.6.5). Moreover, MU's knowledge of functional properties of living things was better in the case of shared relative to distinctive information, a difference that is statistically significant (section 5.5.6.4).

Therefore, in the last experimental investigation (5.6), in the light of Moss and Tyler (1997) observations, a new series of tasks took into account specific and general sensory features of animals in order to account more tightly for MU's knowledge of sensory features. General sensory properties of animals were found to be much more intact in MU than those associated to specific attributes (section 5.6.2.1). His performance with this task seems to be partially in contrast with the results obtained in the feature verification task (section 5.5.6.5), therefore providing empirical support to Tyler's (Tyler and Moss, 1997; Tyler et al., in press) predictions of the preservation of general sensory properties relative to specific ones in patients showing a category specific deficit for living things. However, it should be noted that, while no effect of frequency was found to affect MU's performance with general sensory features of animals, a clear influence of the same factor was observed on MU's performance in the case of specific features (section 5.6.2.1). Therefore, the fact that general sensory properties are much more resistant to damage, and consequently better preserved in MU, might well depend on their high frequency. Thus, further effort should be made in order to control this and other possibly confounding factors to achieve a clearer picture of this phenomenon.

Moreover, sensory properties of animals are characterised by specific functions, inasmuch as they accomplish some purposes (section 5.6.2). In this view not only general sensory features are linked to an explicit function —i.e. stomach/digesting—. However, this might be true also for specific sensory features, although the link to their function is not as straightforward —i.e. horn/defence—. This view seems to contrast with that held by Tyler and Moss (1997) and Tyler et al., (in press), since these authors exclude that highly specific sensory features can have a function, although of minor relevance as respect to fundamental biological functions, suggesting that specific sensory features of living things have just a role in associative and contextual specifications of the concept. However, on lines with Tyler and Moss, MU's knowledge of the functional role of sensory attributes was intact only in the case of general features, while his functional knowledge of specific properties was severely defective (section 5.6.2.2). However, as observed in the comparison between general and sensory features of animals, also in this latter task an effect of word frequency was observed, therefore suggesting caution in drawing conclusions from this finding.

An issue that has never been addressed so far refers to the information relative to the action connected to sensory properties (section 5.6.2.3). Self-generated movements characterise animate kinds concepts (Mandler, 1992). However, also sensory features, at least those of animals, can accomplish highly distinct movements. Although some suggestions about the role of action information have been proposed in respect to the man-made artefacts class, no empirical investigations on the influence of action information on sensory properties knowledge have been carried out so far. However, a very preliminary study of MU's competence in dealing with action information related to sensory properties (5.6.2.3) shows that the patient's knowledge as regards both general and specific sensory features is quite preserved, and no statistical differences arise between the two types of sensory properties in an analysis of covariance. Moreover, an effect of frequency was not found for MU's performance with either type of semantic features in this task. This quite unexpected finding might suggest that action information related to sensory properties of animals could be perhaps separately represented within the semantic memory system. Moreover, the weight of this type of information on functional knowledge of sensory features has yet to be ascertained.

6.6.1.2 Objects, function and action

In a preliminary series of tasks (section 5.6.4) a particular effort was made in order to disentangle the knowledge patient MU has of the "use of an object" ("pure functional information") in comparison with the "way in which an object can be used" ("affordance to action"). Therefore, although MU' semantic knowledge about man-made artefacts was relatively well preserved in contrast to living things and "mass", his ability to identify objects which do not imply any specific action was mildly defective, showing instead a clear and significant advantage with objects suggesting a single, unique action by which they can be used (section 5.6.4.1). Moreover, when his ability to judge pairs of objects on the basis of functional- or action- related information was examined, an advantage favouring action-based judgements (section 5.6.4.4) with respect to function-based judgement (section 5.6.4.3) was found. Therefore, it seems that his performance with man-made artefacts stimuli might be possibly sustained by information related to affordance.

Therefore, this finding presents a pattern of performance in MU which contrasts to that described by Buxbaum and Saffran (1998) of a better performance with function-based comparisons with respect to equally manipulable objects in a group of aphasic patients with an apraxic deficit. Therefore, these data taken together, seems to suggest that properties of semantic knowledge, such as functional and action information, might be at least partially separable in the semantic system organisation. Obviously, the present findings are based on a limited set of tasks and they should be considered only provisional, but a clear trend emerges, highlighting that action-related information might play a much more important role than previously hypothesised in patients' performance on semantic knowledge tasks exploring the functional/sensory distinction.

The intimate relation between functional and action knowledge, both in the case of animate kinds and with man-made artefacts has not been closely investigated so far, and in our opinion the effects found in this work might be valuable indications for further studies to be carried out on this novel ground.

6.7 Final conclusions

The present findings, taken as a whole, challenge Caramazza and Shelton's (1998) assertion that category specific disorders, involving either living things/foods or artefacts, arise because of the selective damage to distinct brain regions subserving the representation of either one or the other of these two different semantic classes. Moreover, Caramazza and Shelton's (1998) criticism based on the observation that an impairment to a given kind of semantic properties is not always reported in patients showing a category specific deficit is quite weak. In fact, MU's impairment can by no means be interpreted just in terms of the selective breakdown of a single semantic domain, because of the findings related to the tight association of living things and "mass" kinds deficit, on the one hand, and the impairment affecting the majority of tasks involving the functional vs. sensory distinction, on the other. Although the influence of feature knowledge on category specific deficits still remains to be wholly clarified, strong suggestions towards a theoretical account which comprises the careful examination of multiple cross-semantic levels of processing come from a number of recent studies of category specificity and from this work as well. The relevance of the adoption of new methodologies and new classes of stimuli has been highlighted in the present investigation. In fact, the novel pattern of findings described in the first experimental section (5.3) received substantial support from the much wider array of tasks and stimuli used in all subsequent investigations (5.4, 5.5 and 5.6).

A plausible way in which the apparent theoretical conflict, found when the whole array of data presented in this work is considered, might be resolved, could imply the development of a computational model which incorporates a sensory-quality/function abstraction as in that of Farah and McClelland (1991), attractor systems as in the model of Plaut and Shallice (1993) and the different type of internal featural relations that living things and artefacts have, of the sort discussed by Tyler and Moss (1997) or De Renzi and Lucchelli (1994), although a redefinition of the "function" concept in terms of manipulability, as suggested by Buxbaum and Saffran (1998), should be implemented in the model. Such a complex model, however, remains to be developed.

On the lines of Warrington and Shallice's (1984) seminal account, a revision of their theoretical proposal is suggested, highlighting the role multiple levels of cross-categorical semantic properties might have in the processing of living things and "mass" kinds. Further investigation of the generality of the semantic deficit affecting the new "sensory-quality" categories should also be critical.

Thus the current findings pose a major problem for theories of the semantic organisation of knowledge, and a reconsideration of the structure and contents of the semantic memory system is suggested.

Figures

Figure 1: Framework illustrating the IAC model of objects processing (Humphreys et al., 1995)

◄──► for excitatory connections; ●──●for inhibitory connections