Scuola Internazionale Superiore di Studi Avanzati - Trieste

THE CONTRIBUTION OF VISUAL SURFACE FEATURES IN OBJECT REPRESENTATION

Evidences from priming and neuropsychological studies

Thesis submitted for the degree of
Magister Philosophae

Candidate: Silvia Pontin

Supervisor: Prof. Tim Shallice

April 2007

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Summary

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...in hvala Gorazd z sonče.

1. General Introduction

1.1. Aims of the thesis

This thesis concerns memory for the objects' appearance. The visual appearance of objects corresponds to a large amount of information, ranging from the global form, the presence of parts and details, the colour and other properties of the surface, such as the pattern, the texture and so on. In detail, we are interested in understanding how we can retrieve from memory information about the colour and the other surface properties of the objects. For instance, how can we know, when we are not looking at it, that the strawberry's colour is red and that its surface is spotted? How is this kind of information stored?

Retrieving knowledge about the visual appearance of objects is a determinant in the recognition process, since it allows the cognitive system to compare what it is perceiving with the stored representations, in order to decide if the object has just been seen, whether it has a meaning and so on.

Starting from the seminal model by Marr (1982), diverse models of object recognition have been proposed, which give differential weight to the surface properties. Some of them claim, for instance, that the objects can be recognized without using colour and texture information, whereas others sustain that the objects can be identified only after the processing of their details. Furthermore, there is no agreement about the relationship between the form-representation (the "structural description") and the surface properties.

We are particularly interested in investigating whether the surface features of objects can be thought as a separate piece of information, sufficient in order to access the complete object representation, including the abstract information about it.

This interest is corroborated by the existence, in the neuropsychological literature, of a debate about opposite theories about the so-called "semantic dissociations". There are patients who typically suffered from temporal lobes lesions, who present with the selective damage of some categories of objects, whereas preserving the knowledge about other classes (for a review, see Capitani, Laiacona, Mahon and Caramazza). Across the theoretical interpretations of this phenomena, it has been suggested that the effect arises when the sensory information (vs. functional, encyclopaedic etc.) is damaged in patients (Warrington & Shallice, 1984).

This hypothesis, that has been further developed during the following years, poses a series of interesting questions about the role of the visual properties in the object representation.

The specific aims of the thesis are to understand whether the visual aspects relative to the objects can be represented independently from the shape-dimension, to define their relationship with the structural description and to understand whether they can be considered a piece of semantic knowledge, sufficient in order to recognize to object and access its complete representation.

In particular, we will discuss a series of priming studies, in which the primes are represented by surface details of fruits and vegetables and animals (see Chapter 3). We will consider the existing literature about object recognition, considering the hypotheses whether the surface features can't be recognized without the presentation of the corresponding form (Walker & Hinkley, 2003). With respect to the nature of the surface features' representations, we will specifically discuss the possibility that variations in the task requirements and the material used in the experiments can determine the activation of diverse kinds of representations, sorting differential results (Price & Humphreys, 1989).

Moreover, we will discuss some models of object processing (i.e. Tyler, Stamatakis, Bright, Acres, Adballah, Rodd & Moss, 2004), derived from monkey localization studies (i.e. Bussey & Saksida, 2002), which propose a hierarchical organization of the object representations in the occipito-temporal cortex.

Crucially, the cortical areas recruited in the object representation process seem to correspond to the lesion localization in the neuropsychological patients who present with semantic dissociation effects. The two patients studied here (see Chapter 4) were presented with a series of classical semantic visual tasks, but involving the object surface details (vs. the object form). As we will see, the statistical analysis on the neuropsychological results don't admit to make strong conclusions (since they fail to reveal strong effects), however, we will still discuss our findings, in a more qualitative way, since they can give interesting insights for the further research in this field. In detail, we will take into account different positions about the interpretation of the semantic dissociation: contrasting, in particular, the so-called sensory-functional theories (Warrington & Shallice, 1984) with more some distributed accounts we will favour in our conclusions (in particular Tyler & Moss, 1997; Damasio, 1989; Simmons & Barsalou, 2003).

Starting from the findings of both the investigations, we will derive a tentative model, which tries to reconstruct the visual representations of objects, comprising form, colour and more detailed visual surface properties.

1.2. Outline of the thesis

In the first part of the thesis, we will consider object recognition, discussing the main models present in the literature (Chapter 2) and we will describe our investigation on healthy subjects, using priming paradigms (Chapter 3). Crucially, in the priming studies, we will use the surface features we are interested in as primes, allowing us to study their role when presented without the corresponding form.

The tasks will vary across the different experiments, with the aim to activate diverse levels of object representation: in detail, and as we will see, an Object Decision will be presented in 3.3, an Object Categorization will be discussed in 3.4 and a Word Categorization in 3.5, respectively.

Furthermore, three final experiments, using a particular kind of priming (Interference paradigm), will be described in 3.6 and 3.7, with the additional aim to test the contribution of colour and texture when separately presented (in detail, see 3.7.3 and 3.7.4).

In the second part of the thesis (Chapter 4), the aims will be considered with respect of the neuropsychological patients. After an introduction about the different positions about category specificity and a brief summary of the theories which explicitly consider the issue of the surface features role in semantic representations (4.2), we will present the two clinical cases, MU and SER (4.3.2, 4.3.3 and 4.3.4).

We will then describe a series of tasks –i.e. naming and matching tasks- comprising both living and non living things' sub-categories, respectively (4.4). After a general description of the patients' performance in these standard tasks, we will present the same tasks, in which the visual objects will be substituted with the surface details: i.e. strawberry -> peel of the strawberry (4.5).

We will then fulfil our aims trying to fit the neuropsychological findings in light of the proposed model (4.6).

2. Object recognition and representation

2.1. Introduction

The Chapter introduces the issue of object representation. The computational and the anatomical perspectives are considered, with the aim to find a point of conjunction between the approaches. We start from recognition (and from perception, in some cases), since it appears clear that the object representation resembles the object perception mechanisms from both the anatomical and the functional point of view. We will introduce some works focusing on the visual features, in particular colour and texture, trying to understand the status of these attributes in memory and the way in which they are integrated with the structural description and with the form information.

The Chapter is divided in three sections. In the first part (2.2) object recognition is defined (2.2.1) and the main models of object recognition are presented (2.2.2); we take into account the problem of the feature binding (2.2.3) and the status of specific features, such as colour and texture (2.2.4), with particular reference to their format of representation (2.2.5). Moreover, a paragraph (2.2.6) is dedicated to the relationship between these features and the object-form representation.

In the second part we describe the ventral visual stream (2.3.1), we specifically consider convergent evidences in the literature corroborating the strong role of the Infero-Temporal cortex in the object representation (2.3.2). Then, we briefly consider two alternative hypotheses about the organization of the neural activity within the occipito-temporal regions (2.3.3), and we consider some suggestions about the representation of different categories of objects in the temporal cortex (2.3.4). A further paragraph is dedicated to one of these theories, that would result quite interesting for our discussion (2.3.5).

Then, we take into account the strong similarity between the occipital visual areas and the temporal regions organization (2.3.6). Finally, two paragraphs are dedicated to studies focusing on the representation of colour (2.3.7) and texture (2.3.8), two visual features which will assume a critical role in the Experimental parts of this work.

The third part of the Chapter (2.4) is dedicated to the perirhinal cortex, as one of the putative more crucial areas for object recognition. After a general anatomical consideration about the rhinal cortex and its connections with the other temporal structures (2.4.1), a model of object recognition and memory based on the perirhinal cortex is presented (2.4.2). Finally, we present a recent study by Tyler et al. (2004) that with some respect binds together different issues about object recognition in a quite comprehensive account (2.4.3).

2.2. Object recognition and feature binding in visual cognition

2.2.1. Introduction and definitions

Object understanding is based on the capacity to recognize the objects, first as separate from the background and secondly as whole entities, formed by the sum of different parts. Object representation in memory can be thought as a process of re-activation of neural activity that corresponds to what was originally perceived. In other words, when an object is seen, the cognitive system activates specific patterns of neural activity in order to capture a specific description of the object itself; this description would allow the cognitive system to recognize the object, whenever it is encountered a second time.

There is empirical evidence in favour of the existence of different types of object representations (Treisman & Kanwisher 1998).

The first two levels of object representation correspond to pre-identity descriptions, which involve a "*conscious viewpoint-dependent representation of the object as currently seen*" ("*object token*") and an object-centred non-visually representation, independent from the point of view ("*structural description*[1]"). In this light, the visual system is supposed to first segregate the objects from the background, allowing "object token" representations, which would in turn activate the further -and higher- levels of representation, in a bottom-up cascade process of activation. The cognitive system isolates different instances of the objects from the visual array and, with time, it binds together all the information according to the spatial and the temporal relations. Interestingly, it has been suggested that top-down processes could also be involved in this first level of representation (Vecera & Farah, 1997): in detail, when

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[1] A good definition of *structural description* is suggested by Palmieri and Gauthier (2004): "a qualitative representation of an object in terms of its three-dimensional primitives –for example "geons" –and their relative positions. Many structural descriptions are devoid of metric information regarding quantitative aspects of the primitives –specific shapes and sizes- and their positions –specific spatial locations-".

high familiar objects are encountered, partial information from the lower levels can be sufficient in order to activate higher representations, which in turn could contribute to the segmentation stage, in a top-down cascade process. The information stored at this level of representation contributes to the object-specific priming.

The structural description level of representation, instead, involves the object identification as a whole entity, in which all the parts/details are summed together and integrated. At this stage the semantic identification and the category belonging are allowed. Moreover, at this level of representation priming effects between objects conveying the same semantic information and between objects and their names are supposed to take place (Gordon & Irwin, 1996).

Further levels of representation allow the identification, the recognition of category membership ("*object type*") and the activation of other types of information associated with the object (i.e. other sensory features of that object)[2]. Two more levels of representation involve the emotional/motivational significance and the so-called "*action centred descriptions*"[3], which convey information about the way in which we can interact with the object (i.e. use, manipulation).

2.2.2. The main models of visual object recognition

Marr (1982) pointed out that two different kinds of theories exist, relative to the way in which the object-structures are derived from the perceptual entries.

The **"*Viewpoint-based*" models** (Bülthoff & Edelman, 1992; Bülthoff, Edelman & Tarr, 1995; Edelman, Cutzu & Duvdevani-Bar, 1996; Poggio & Edelman, 1990; Tarr, 1995) state that the objects are perceived as holistic entities (differentiated on the basis of the spatial relations specific for their point of view). These models assume that the visual system does not separate the objects' parts, but it perceives them as unitary elements, strongly relying on specific spatial point-of-view-based features. These models are good in order to explain the identification of the individual instances, but they are unable to explain how new elements are recognized as category-members (Hummel & Stankiewicz, 1998). Moreover, as Marr underlined, a "*potentially large store of descriptions in memory*" is needed in order to "*compensate for the effects of perspective*"; in other words, these models recognize as different

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[2] The levels from 1 to 4 (i.e. Object token, Structural Description, Object Type and Semantic Knowledge levels of representation) are supposed to depend on the ventral-occipito-temporal areas.

[3] The levels 5-6 (i.e. Emotion/Motivation level and Action-centered representation) are supposed to depend on the dorsal-occipito-temporal areas.

items the same object presented with different orientations and diverse spatial features.

On the other side, the ***"Structural Descriptions"* models** (Biederman, 1987; Dickerson, Pentland, & Rosenfeld, 1992; Hummel & Biederman, 1992) state that an object is seen as a summation of parts, which contribute to the representation of the item in terms of spatial relations. These models are directly developed from the Marr's theory of recognition, in which the problem of different orientations is circumscribed by the assumption that an object-centred coordinates system sustains the object identification. In the Marr's model, a single description would be sufficient in order to describe different view-points of the same object; quite obviously, the extraction of such a description from the perceived object would be harder than in the viewpoint-based models, since it has to occur before the description is identified in memory. The Marr's recognition model assumes also that the object's descriptions correspond to a series of *primitives*, which are defined as *"the most elementary units of shape information available in the representation"* (see Marr, 1982, page 302). These units, which convey information about the location, the size, the orientation and the spatial distribution of a shape, are supposed to be organized in a hierarchical way, with the global information about the rough shape at the top of the hierarchy and the detailed information at the lower levels. Marr also specified the way in which the description derived from the perceived object can be compared with the stored models; this can happen using a "specificity index", a sort of process through which the description derived from the object (i.e. what Marr calls 2-D sketches) is compared with the stored models. "Going through" the hierarchy of the stored representations, the perceived object, represented as a description, is -first- compared with the global model, and -then- with more and more specific models within the hierarchy, until the most similar description is found. Other indexes are thought to exist for the correct association of the perceived object and the stored models: they can allow the identification of the correct size, the location and the possibility to identify the whole object representation even if no global description is allowed from perception (i.e. when the part of the object is obscured by other elements). Interestingly, Marr also admits the possible existence of indexes relative to other object-features, such as colour, texture, sounds etc. which can be helpful to recognition.

Similarly to Marr, Biederman (1987) proposes a model in which the object recognition is mediated by simple volumes representing the gross shape, the so-called *"geons"*, which capture the basic shape's and the parts' visual appearance. For instance, an apple can be identified as a sphere-shaped object with additional part-elements (i.e. *stem >> small cylinder*). In this view, the spatial relations between all these elements become crucial in order to reconstruct the whole object: this process comes out in a *structural description* that puts together all the information about the shape, the parts and their relative spatial positions. Moreover, these models propose a hierarchically organized reconstruction of the structural descriptions that starts from the general shape and in which the details and the specific aspects are supposed to be added at different steps.

2.2.3. Features and the binding problem

Since the identification requires the matching of what has been seen with the stored representations, it becomes crucial to understand how the different sources of information derived from the objects (i.e. shape, parts, colour, texture, luminance, size) are bound together for achieving a complete target-representation and how these aspects are represented in memory.

The viewpoint-based models assume that the cognitive system recognizes the objects as unitary entities, without matching the separate aspects with the corresponding memory representations. In such views, the binding problem assumes less importance than in the structural description models, which claim, instead, that different object-parts contribute as separate units to a complete structural description. These models suggest in fact an explicit representation of the object's parts by the visual system (Biederman, 1987; Tversky & Hemenway, 1984; Marr, 1982 and Marr & Nishiara, 1978).

The binding problem remains in general quite controversial and different hypothesis have been suggested about how the system can reconstruct a complete object representation (see Treisman, 1999 for a review).

An attempt to solve the problem of binding comes from Hummel & Stankiewicz (1998) and developments of his study (Hummel 2001; Stankiewicz & Hummel, 2002). In Hummel's view, different processes underlie the attended (learned) and the unattended (novel) object recognition. When an attended object is perceived, the recognition can rely on the structural description reconstruction. In this case, the "dynamic binding" would occur: a single representation is used, in a flexible way, for several combinations of features, allowing the object recognition from different points of view (representations invariant from spatial changes). The dynamic binding results in a synchrony of firing at the neural level, which mirrors the combination of different features in a unique representation (i.e. Singer, 1993 and Hummel & Biederman, 1992). On the other side, when a non-attended object is encountered, the system can not rely on a one-to-one structural description matching, so that a "holistic" representation of the object is needed (e.g. not implying parsing of object parts and different information sources). This means that separate units are activated for different combinations of features, strictly depending on the spatial changes. In summary, the Hummel's model allows different kinds of representation for the attended and the not-attended objects, claiming a strong role of the attention in recognition.

Similarly to some respect to the Hummel's suggestion, the Treisman's model of feature processing and binding assumes that the object's features are firstly perceived together (mediated by their spatial and temporal positions) and only in a second stage, after several presentations of the same object, they can be separately activated and represented.

Thus, differently from the viewpoint-based models, both the Hummel's and the Treisman's solutions to the binding problem allow, at least for some specific conditions, the separate representations of the object's features, which require an active binding. Crucially, both the models suggest a strong interaction between the actual perception and the long term memory representations for the single features as well as for the global "holistic" object representation (separate representations of the single features are expected for the well known or the attended objects).

Interestingly, Tanaka (1996) emphasizes the fact that binding "*exists regardless of the presence or absence of "conceptual units" representing the concept of objects* [...]". In his model, different neural units -representing the object's features- are simultaneously activated (synchronized firing) and come out in a whole-object representation; however, several objects can activate the same neural units in different patterns. In this light, the conceptual units can play a role in differentiating between sets of units and in recognizing the right object[4].

2.2.4. Colour and other surface details

A further division of the models of object recognition can be made according to the importance given to the surface details (i.e. colour and texture). Some authors do not consider colour and texture as crucial dimensions for the object recognition: across them, Biederman & Ju (1988) stated that the object recognition relies on edges

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[4] For details about the Tanaka's position, see paragraph 2.3.2.

and contours detection, whereas the surface details are not needed in recognition, and that they can be activated as "later" representations after the identification. On the other hand, there are models which emphasize the contribution of colour and texture in the object recognition. Marr's model (1982) gives strong importance to the surface features in the object recognition and representation, since colour, texture and shading can contribute to the 2 ½ D Sketch.

There are studies which focus on the specific role of colour and other surface details (i.e. texture) in object identification, with particular respect to the level of representation required by the task.

In a series of experiments, Price & Humphreys (1989) presented the subjects with naming or categorization tasks, using categories which items varied in terms of the structural similarity. The structural similar categories consisted in visually similar objects (i.e. *fruits*), while the structurally dissimilar categories were formed by visually different items (i.e. *furniture*). Moreover, the authors employed coloured and black-and-white photographs as well as coloured, black-and-white and wrongly coloured line drawings of the same objects, so that they could isolate the contribution of the different surface aspects (i.e.: colour vs. texture using coloured vs. black-and-white photographs; texture vs. no surface information using photographs vs. line-drawings). The idea underling the study was that colour and surface properties could differently contribute in the structurally similar and dissimilar categories; moreover, an effect of the task was expected, since naming was supposed to require a finer discrimination of the items.

The authors found that the coloured items were named faster than the other items, and that the subjects were faster in naming the black and white photographs than the line drawings, in particular for the similar categories; furthermore, they failed to find an enhanced effect when the colour and the texture were both present in the target (i.e. coloured photographs vs. coloured line-drawings). A general facilitation effect of the colour and the texture was also evidenced in the classification task, where the latencies were faster when the coloured photographs or the line drawings were presented (vs. the black and white targets); moreover, faster responses were found for the black and white photographs than the line drawings, evidencing an effect of the texture as well. The structural similarity had a role, since the similar categories were classified faster than the dissimilar ones; moreover, a larger number of errors was observed for the dissimilar categories when wrongly coloured. In a further but similar experiment, only the "*similar*" categories were used in a categorization task: in this case, and in line to the previous findings, colour influenced the latencies, whereas no effect of the texture was found. A third experiment aimed to verify the specific relationship between the colour and the shape, through the manipulation of the locus of the colour appearance within the picture. In detail, the subjects were presented with the correctly coloured line-drawings or with the same line-drawings which colour was used as the background instead of the filler. Interestingly, when the colour did not fall into the object, but was used as the background, the facilitation effects did not emerge.

From all these findings, Price & Humphreys concluded that the surface information can have an influence on both the naming and the classification tasks; furthermore, they claimed that the surface properties' role in the object processing is a function of the rate-limiting processes of performance and of the degree of the items-differentiation required by the tasks. This would explain, in their view, why stronger effects were found for the similar categories in naming, whereas no differences between the tasks were observed for the dissimilar classes of objects. In their opinion, when the exemplars of a structurally-similar category are named, a fine within-category discrimination is needed, while a broad-level discrimination is sufficient in order to solve a classification task. On the other hand, when the dissimilar categories are taken into account, the degree of discrimination required for naming and categorization is about the same, so that no differences emerge between the two tasks.

Another interesting result of this study was the lack of enhancement due to the presentation of bound colour and texture. The authors claimed that these features are initially processed separately and that they affect the performance only in a short-time window, so that when they are combined their single-effect is yet saturated. Moreover, when a later process is required (i.e. when the task requires a high degree of discrimination and a specific semantic activation), the texture effect are washed out, suggesting that at this stage the colour plays a more crucial role.

All these findings were interpreted in light of a cascade object recognition model (Humphreys, Riddoch and Quinlan, 1988 - see Chapter 4, paragraph 5.2.1.3 -), assuming that an object is initially recognized on the basis of the shape-features (edge-based recognition), and it is then "specified" by the processing of the surface details, which contribute to the fine identification and the discrimination between the exemplars. However, when the full semantic activation is reached, the earlier effects are in some way annulled or weakened. In such a model, the full object representations can be activated before the complete semantic access, allowing the naming at the early stages, at least for the structurally dissimilar categories.

An interpretation in terms of the required level of discrimination also explains why different effects are found in the classification for the similar and the dissimilar categories (stronger effects in naming than categorization for similar categories; stronger colour effect on categorization for structurally dissimilar categories). Finally, the authors claimed that the texture has not the same semantic value than the colour, and for this reason it has no effect in the fine classification tasks.

Similarly to Price & Humphreys (1989), Ostergaard & Davidoff (1985) brought evidence in favour of an effect of the colour on object naming. They presented an object naming and an object-colour naming task, in which the stimuli were varied for the presence of colour within the picture; moreover, they reported the results of a colour naming task in which the stimuli could be objects, meaningful geometrical shapes or meaningless geometrical shapes. They found a general facilitation effect of the coloured over the black and white pictures, whereas no difference between object and colour naming was evidenced for the coloured pictures. Moreover, they found no differences between colour naming of objects and patches of colour or between meaningful and meaningless shapes. A second experiment, involving only coloured objects, and in which colour was varied with respect to the appropriateness[5], replicated the finding that colour had an effect on object naming but not on simple patches; furthermore, no effects of colour were found in a recognition task. The authors interpreted these findings as the proof that colour plays a role on naming tasks, while it has no effect at other (previous) levels of processing, such as recognition. They claimed that colour is one of the object physical attributes that are "*listed in semantic representation*" and that it is verbally coded: this was suggested since colour had no effect on the recognition stages, while it interfered with the naming process (that is supposed to require semantic access).

Colour has also taken into account as a diagnostic dimension for the object recognition. For instance, Tanaka & Presnell (1999), showed that the colour-presence facilitates naming, recognition and verification tasks when diagnostic-colour objects (vs. low diagnostic-colour objects) were used.

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[5] The authors considered an association between the colour and the shape as "appropriate" when it respected the original appearance of the object: i.e. a red apple.

2.2.5. The nature of visual features representation

In general, all the reported studies conveyed evidence in favour of a long-term memory representation of the surface details (in particular: colour). A main problem concerns the nature of the colour (and texture) representations: it is in fact possible that colour contributes to the object recognition only at the perceptual level; alternatively, colour may cooperate at later stages of representation, at which semantic access is supposed to occur. This issue has been partially taken into account by Price & Humphreys (1989), which proposed that colour and texture influence on object recognition can be modulated by both the task and the target characteristics. In other words, when a detailed discrimination is needed, the surface features become crucial, excluding the possibility of an all-or-nothing influence of such features on the object processing.

Davidoff & Ostergaard (1988), in a development of their previous study (Ostergaard & Davidoff, 1985), contrasted categorical judgments vs. naming task, in order to understand the precise level at which colour could play its part in the object representation. The stimuli consisted in appropriately or inappropriately coloured objects. As a main result, an effect of colour was found only on naming, and it was interpreted as a replica of Ostergaard & Davidoff (1985); moreover, the authors suggested that colour not only has no effect on recognition, but it can't influence semantic tasks (categorization) "earlier" than naming. With respect to the level of representation at which colour can play its role, they referred to the Morton's Logogen Model (1979). In the Morton's model for word recognition, the input can be visual (written word) or auditory (spoken word) and it is decoded in two separate modules, which are devoted to the visual and the acoustic analysis, respectively (see Figure 1). These analysis systems in turn send information to the so-called "Logogen", a memory store for the lexical entries derived from the input. This central module is in communication with the semantic memory (the "cognitive system"), in which all the information derived from the input itself and its context are bound together. The Logogen system sends information to a response buffer that gives response to the initial input (i.e. reading or repetition the word).

Ostergaard & Davidoff suggested that the colour can interact with the phonological output, while it has no influence on the semantic tasks relying on the visual presentation (i.e. picture categorization).

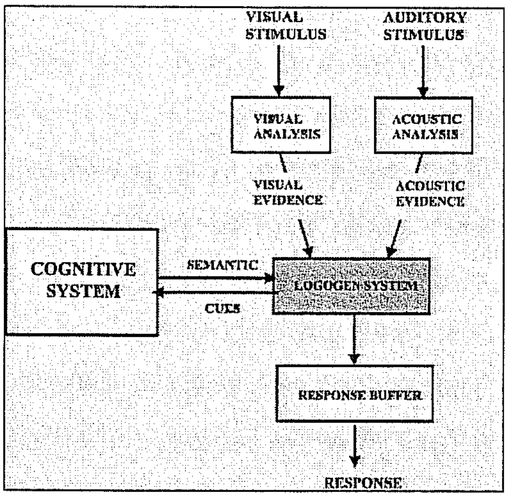

Figure 1. The Morton's Logogen Model (1969). Redrawn from Morton (1979:138). This version Copyright © 2002, Derek J. Smith.

They thus concluded that colour is quite certainly represented in a semantic space (see above), but its representation is not "pictorial", since no effects of this dimension are found for the picture recognition/categorization tasks; on the contrary, they claimed that the colour is represented in a verbal format, since it can interact with the naming processes.

2.2.6. The relationship between shape and colour (and other surface details) representations

The specific relationship between the shape and the colour in object representation has been recently investigated by Naor-Raz, Tarr and Kersten (2003). In their study, they manipulated the colour of objects (or the corresponding words), presenting the stimuli with their original (diagnostic) colour or with an unreal colour (i.e. *banana*: yellow vs. blue). They used a Stroop-like paradigm (the subjects were asked to name the colour, instead of the object or the word) with the intention to bypass the semantic activation that could derive from the object naming. They found that the correct colour had a facilitation effect on the colour-naming, while a slowing down of latencies was observed in the case of the word-naming. The authors interpreted this suggesting that in colour-naming no lexical or semantic activation is required, and colour plays its influence at the visual level only. On the contrary, they stated that the lexical entries (corresponding to the target-word) are activated in both the word- and the colour-word reading, resulting in a conflict between two lexical different answers; in turn this conflict would determine the slowing down of the latencies. In general, this study sustains the idea that the colour plays a role at the early stages of the object representation, i.e. visual representation, while it has no contribution at the semantic level. This suggestion was corroborated, in the authors' view, by a further experiment, in which the same colour-naming task was followed by a lexical decision on a word related or not to the target. They failed to find an effect of the relatedness, and they interpreted this as a proof that the lexical-semantic representations were not activated. The authors concluded that *"it appears quite impossible to process colour independently from shape-dimension"*, whereas the shape has a strong role in the object identification.

Walker & Cuthbert (1998) aimed to demonstrate that (short term) memory for the features' conjunctions is object based. They were interested in replicating the so-called Unitization Effect (see Ceraso, 1990), for which the presence of a feature within the shape-frame facilitates the memory for the shape-attribute conjunctions, whereas the feature-shape association is weaken by the presentation of the attribute outside the shape frame. In order to investigate this effect, Walker & Cuthbert developed an experiment in which the subjects were presented with colour-shape associations and manipulated pictures, so that colour could fall within the object-shape or in the object-background. They showed that the Unitization effect arose when the verbal encoding of the material was avoided, but it disappeared when the verbal strategies were allowed (since, they claimed, the verbal mediation reinforced the conjunctions for the separate attributes).

Starting from the Walker & Cuthbert's conclusions, Walker & Hinkley (2003) aimed to investigate whether the shape representation that allows the feature-conjunctions' memory is "pictorial" –and thus conveying full visual surface information about the stimulus- or "abstracted" –representing visuo-spatial information in a structural description-like format-. They used alphabetical letters as shapes, manipulating them in order to allow or prevent the structural description mediation (font and case changes, respectively). The letters were presented in different colours, and the task consisted into remembering the shape-colour associations. The main result of their study was that the memory for the letter-colour associations was mediated by the structural descriptions (no effect of the letter font). Moreover, the authors excluded the mediation by the verbal/abstract representations, since an "effect of letter case" was found (the subjects treated the same letter presented in different cases as diverse objects).

In another work regarding the representation of the object's shape/colour, Hanna & Remington (1996) varied the colour of the geometrical shapes from the study and the test phase (in a recognition memory task). In a first experiment they considered the colour presence as the critical variable: they found an effect of facilitation when the colour was presented both in the study and the testing phase, result confirmed the colour role in the long term memory object representation. In a second experiment the shape-colour conjunctions were manipulated, evidencing at least no significant effects when the colour was changed (substituted with a different one[6]): this last result was interpreted as the index of a separate status of the colour and the shape representations in memory.

Finally, in a more recent study, Nicholson & Humphrey (2003) specifically tested the hypothesis that the colour and the shape are both "*automatically encoded in long-term object representations*". They employed novel objects as stimuli in a series of shape recognition tasks, with the aim to prevent both the verbal encoding and the mediation by the previously learnt colour-shape associations. The colour was varied in the targets to be recognized, with the idea that the facilitation in identifying a just-presented object when its colour was not changed would be due to the automatic encoding of *colour+shape* in memory. The findings showed no effect of the colour manipulation on the accuracy ratings, whereas faster latencies were associated to the targets maintaining the previously associated colour. The authors interpreted these results as the proof that the colour and the shape are represented together, even if a separate processing of the shape is possible. In the same study, a further experiment was presented in which the colours of the object-parts were varied, so that the participants had to label an object as "old" only when both the colours and the colours-disposition within the shape had just been seen. The results were similar to the first experiment, suggesting that memory for the shape-colour conjunctions is quite specific. Nicholson & Humphrey suggested two alternative interpretations of their findings. A first possibility, in line with Price & Humphreys (1989), is that colour and shape are represented separately, but they are strongly interconnected, so that a facilitation occurs when they are reactivated simultaneously. The second proposed possibility is that the colour (plus *other surface properties*) and the shape are integrated in memory, through an automatic coding; they sustained this interpretation referring to cell registration studies (Tanaka, Saito, Fukada, Moriya, 1991; but see

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[6] Further manipulations were introduced (i.e. colour vs. absence of colour), which are not commented here.

also Tanaka, 1996), in which a stronger activation is found for the combination of features than for the single attributes presentation.

2.3. The neural representation and the anatomical localization of shape & visual features

2.3.1. General anatomical introduction

It is well known that two separate pathways devoted to the visual processing exist at cortical level (Ungerleiter & Mishkin, 1982). The visual information, firstly processed in the occipital areas (V1, V2 and V4), gives rise to two separate streams of activation, directed to the parietal and the temporal cortices, respectively. The first stream, the dorsal pathway, conveys spatial and motor information, and contributes to the functional processing/programming of the grasping, the action and the motion interpretation. On the other side, the ventral stream, which brings the visual information from the visual occipital areas to the temporal lobes, is devoted to the recognition, the objects' differentiation and the similarity depicting.

The evidence in favour of a visual specialization of the ventral steam comes from monkey lesion studies: it has been shown that the ablation of the anterior temporal cortex creates visual recognition deficits (Bayliss, Rolls and Leonard, 1987), while the monkeys without the inferior temporal cortex show problems of object discrimination. Furthermore, learning deficits (in visual recognition tasks) have been found as the consequence of the bilateral TE ablation (Gross, 1973).

From a strictly anatomical point of view, the information coming from the visual occipital areas reaches TEO and, subsequently, TE, two monkey-brain areas which approximately correspond to the anterior infero-temporal cortices in the human (Figure 2).

TE is considered as the last purely visual area in the ventral stream; it is strongly in communication with the medial temporal lobe and projects to several polymodal areas, including the perirhinal cortex, the prefrontal cortices, the amygdala and the nucleus striatum.

The occipital visual areas, TEO and TE can differ with respect to their organization and the kind of representations conveyed. In detail, TEO contains cells which resemble the V4 neurons, in that they respond to simple visual stimuli; on the other hand, recent investigations showed that TE and V1 differ with respect to the axonal organization (Tanigawa, Wang and Fujita, 2005): TE appears to be not organized according to retinotopic maps; furthermore, the axonal connections from (and to) TE are organized so that adjacent regions in TE project to widely distributed cortical sites, allowing both the convergence and the divergence of visual information within the temporal stream.

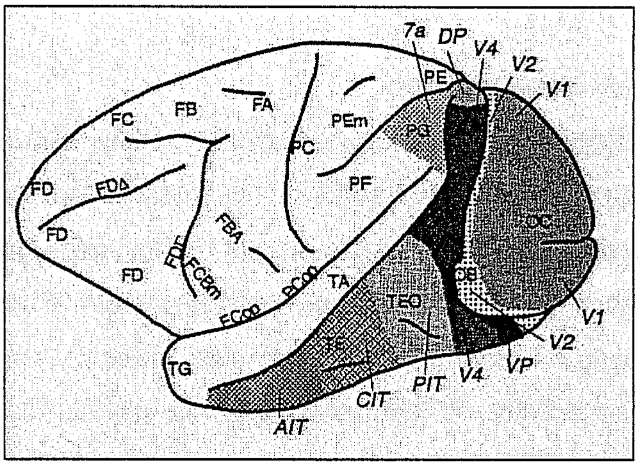

Figure 2. Map of lateral surface of the Macaca mulatta brain from Von Bonin & Bailey's (1947), on which major visual areas (from Felleman & Van Essen, 1991) have been superimposed –taken from Logothetis & Sheinberg (1996)-. **V1, V2, V4** = visual areas; **VP** = ventral posterior visual area; **PIT** = posterior inferotemporal; **CIT** = central inferotemporal; **AIT** = anterior inferotemporal; DP = dorsal pariatel; **TE** and **TEO** areas are also visible.

This suggestion is in line with recent studies on the monkey IT (see later, paragraph 2.4.2: Saksida, Bussey and Murray, 2000 and developments), which hypothesise that the posterior temporal neurons represent simple features, while the anterior cells are devoted to represent the features' conjunctions, thus responding for complex stimuli.

2.3.2. The role of Infero-Temporal Cortex role in object representation

Several studies have demonstrated the specific role of the infero-temporal cortex in the object representation. For instance, Kovacs, Sary, Koteles, Chadaide, Tompa, et al. (2003) have shown that the Macaque IT cortex is selectively activated for the shape presentation. Furthermore, they find a slight modulation effect on the cortical activation due to changes in the objects' shades and textures, even if in general they failed to find neither an influence of these features nor an effect of the object internal edges on the neural activity.

Moreover, the cell recording studies have shown that the infero temporal cortex responds to both simple visual configurations and complex stimuli (Tanaka, 1996; Logothetis, Pauls & Poggio, 1995).

Tanaka (1996) proposed a model of the IT cortex organization, based on the findings coming from monkeys' cell registration studies, in which he demonstrated the TE selectivity for stimuli put in the same frontal plan, or having the same size; moreover, he showed that the cells in this area were sensitive to the stimulus rotation and changes in the contrast and the contours. Tanaka brought evidence in favour of a columnar specialization of the neurons in TE, resembling the organization of the occipital cortex. He claimed that one cell is not sufficient to represent a whole "naturalistic" object, but it can be activated for complex stimuli; furthermore, TE was thought to be a columnar space, with the close columns processing similar information and the cells within each column selectively responding to the same material (similarly to the occipital cortex organization). With respect to the more posterior temporal areas (i.e. area TEO), TE seems to be more selective for the specific visual stimuli: it has larger receptive fields and it seems to be feature-specific. Basing on these findings, Tanaka hypothesized diverse specializations for the different areas within the temporal cortex: in detail, TEO (receiving from the occipital visual areas) would send different kinds of information about the complex features to TE; in turn, TE would code and integrate information using its columnar organization. The recognition is sustained by the columnar organization in TE since these modules are specialized for specific information, quite invariant from the orientation, the size and the other context factors. Moreover, since close cells can be selective for similar material, resulting in an overlapping pattern of activation, the object representation becomes more precise than it would be by the mere summation of the single cells activity.

In summary: Tanaka claimed that TE cells are represented in columns, which can be organized as larger modules; they receive input from the visual areas, through the TEO mediation. The columns within each "module" are in communication, sending each other excitatory inputs. All this determines a larger pattern of activation which is characterized by a central focus. In addition, he proposed possible solutions to the binding problem, suggesting that the synchrony of cells-firing would be one of the basic mechanisms responsible of the features integration, together with an attentive process of selection; furthermore, he proposed the presence of loops of activity, organized through the help of feedback projections.

Tsunoda, Yamane, Nishizaki and Tanifuji (2001) further developed Tanaka's model, bringing evidence in favour of the columnar organization of the visual representations within the temporal cortex (see also Tanaka, 2003). In detail, they recorded from the macaques TE cortices, while the animals were looking at visual objects with different combinations of features (i.e. shape, colour). Their findings showed that the TE neurons selectively responded to the single features, but that they were also activated as complex patterns, with the contribution of the active and the inactive columns. They interpreted this as a suggestion in favour of a complex organization of the TE columns, in which the activation and the *inhibition* parallel mechanisms played their role. In other words, when presenting a complex stimulus, some columns would be activated by the presence of the feature *x*, whereas other columns would be inhibited by the absence of the feature *y*.

Further evidence supports the idea that the inhibition mechanisms can contribute to the inferotemporal cortex organization. For example, Wang, Fujita and Murayama (2000) explored the TE clusters-organization in monkeys, blocking the action of GABAergic receptors within TE and thus preventing the inhibition processes. The result of this blockage was an alteration of the input-selectivity in the TE neurons. In detail, some cells were found which responded more to the stimulus to which they were initially specific for. From this, the authors claimed that a certain quantity of the input which arrives to TE is usually blocked by the inhibition processes (GABA-mediated) and that for this reason the blockage of the GABA receptors comes out in a general augmentation of the responses. These findings were interpreted as the demonstration of a columnar organization in TE whit a heterogeneous interconnectivity, of the presence of inhibition-mechanisms allowing the suppression of some inputs from TE, contributing to the stimulus-specificity for the single columns and to the functional organization of the TE columns. The inhibition mechanisms blockage was used also in another study (Jagadeesh, 2000), in which some neurons, initially specific for a certain stimulus, became more responsive for another stimulus, similar, but not identical to the original one. The author suggested that the adjacent columns, which respond to different but similar features, can inhibit one each other contributing to the general organization of the inferotemporal region.

Finally, further evidence in favour of a refined specialization of the IT neurons for the visual features comes from Sigala & Logothetis (2002), who trained the monkeys in a categorization task, employing faces and fish shapes as targets. The stimuli were manipulated so that changes in the features (i.e. eye-mouth distance) would create two different sets of items within both the faces and the fishes. In this way, and for each class, they recorded from IT, finding that the neurons of this area respond to all the stimuli, independently from the category of belonging; moreover, they found a high degree of selectivity for the diagnostic features (that is, features useful in order to discriminate the two sets within each class). Sigala & Logothetis interpreted these results claiming that this specialization of IT "*provides a mechanism through which feature diagnosticity shapes the encoding and the perceptual interpretation of visual objects*".

2.3.3. The neural models: Distributed vs. Holistic coding

Tsunoda et al. (2001: see 2.3.2) interpreted their findings in light of the Tanaka's model, claiming that a columnar (modular) organization would be more likely to be the principle on which the object representation is sustained within temporal cortex, than a object-based representation model. Relative to this issue, two kinds of models of the neuronal representation have been proposed in the literature.

In the **distributed coding models**, entire populations of neurons are supposed to be activated to represent a whole object (Pasupathy & Connor, 2001), while specific pieces of information correspond to different neural nodes. In detail, there are findings supporting the idea that objects are represented through "parts" (Tanaka & Taylor, 1991; Bruner, 1957; Sands, Lincoln & Wright, 1982); moreover, some neurons in the ventral pathway have been identified which are devoted to "fragments" of the objects representations (Sughiara, Edelman & Tanaka, 1998; Pasupathy & Connor, 2001), "geometric elements" (Tsunoda et al. 2001) and "surface features" (Tanaka et al. 1991).

In opposition to the distributed coding models, the "**holistic theories**[7]" state that each neuron code for the prototype shape similarity (Poggio & Edelman, 1990; Edelman, 1999). In favour of these models, selectivity has been shown for different view-points of the same object (Logothetis & Pauls, 1995; Booth & Rolls, 1998[8]); moreover, increased selectivity has been observed in monkeys IT for the whole object configuration of learned shapes (Baker, Behrmann & Olson, 2002).

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[7] A definition of what is meant by "holistic" is given by Kanwisher (2000), in a commentary concerning face-representation: "[...] One possibility is that a holistic processing of face results from the tendency of face-selective cells to respond to the whole face, rather than to parts of the face." [Kanwisher, 2000; page 761].

[8] It is worth noting that the same authors suggested a distributed object representation in IT, in which different units, responding to the different view-points, contribute to a whole-object representation.

Despite the contraposition between the Distributed and Holistic models, Baker et al. (2002) proposed that they are not mutually exclusive, since different levels of encoding and representation can contribute to the shape/object recognition. They presented trained monkeys with two features within a complex object (i.e. manipulating the starting and ending part of an arrow), while recording from IT. They found an increased response in IT after training, and, crucially, they observed a significant "holistic effect" for the learned stimuli: this was interpreted as the proof that the cells were selectively responding to the complex stimulus (i.e. the specific conjunction of starting+ending of the arrow). In the authors' view, these findings corroborated the idea that the complex stimuli are represented as "holistic" entities, at least for "[...] *familiar, behaviourally relevant shapes*". Anyhow, the authors found also a part-based activity within the infero-temporal cortex, elicited by the same material, evidencing that a parts-based representation is still working. They claimed that the two kinds of representation can have a different functional role: holistic representation would be dedicated to the familiar and well learned material; the part-based coding, which is more flexible, would be more useful when new stimuli are encountered. Moreover, parts-based representations can contribute to holistic representations, which in turn would be useful to reduce complexity and to perform similarity judgments and comparisons between different objects.

2.3.4. Infero-Temporal Cortex selectivity for categories of objects

Different hypothesis have been advanced with respect to the functional organization of the temporal cortex (see Grill-Spector, 2003).

- Strong evidences in favour of a **modular organization of objects** within the brain come from studies on face-recognition. In her review of the specific literature, Kanwisher (2000) commented about a large amount of evidence coming from both the normal subjects' and the neuropsychological patients'[9] investigations, which corroborate the idea of a modular representation of the face, localized in the fusiform gyrus.

More recently, Grill-Spector, Knouf and Kanwisher (2004) showed, in a fMRI study, that the fusiform gyrus responded selectively to the faces (vs. other objects –

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[9] I.e. inversion effects, in which the normal subjects are slower in recognizing particular features of the faces when the faces are turned up-down, while the same effect is not found for other objects; a holistic advantage in the perception of the faces, the existence of pure prosopagnosic patients etc (see Kanwisher, 2000 for references about these studies).

i.e. guitars, flowers, houses); moreover, they evidenced that this area was activated by both the detection and the identification of the face, contrary to the hypothesis that this region is involved in a purely perceptual processing. Finally, they found an activation of other areas during the presentation of objects, while the faces were associated with a strong fusiform area activation only. All these findings were interpreted in light of a high specialization of the fusiform area and against the alternative hypothesis that it could be activated in general "within-category" discriminations (i.e. for whatever category of objects presented).

Besides the face-specificity within the brain, other categories of knowledge have been indicated in the literature as possible candidates of a modular representation. In particular, Caramazza and Shelton (1998) proposed that the evolutionary pressures determined the specialization of cortical areas for few categories of natural objects, which are crucial for the human species survival (i.e. the edible things, the predators, etc.), while other classes of things (i.e. the artefacts) would be represented in the brain "*by-difference*" from these important classes[10].

Imaging studies have shown the different activation of diverse classes of objects (i.e. animals, tools, letters and faces) within the temporal cortex. For example, in a PET study, Damasio, Grabowsky, Tranel, Hichwa, and Damasio (1996) showed that naming animals selectively activates the middle temporal gyrus, while other works evidenced the activation of the inferior temporal gyrus for manmade objects to both the visual and the tactile stimulation (Ishai, Ungerleider, Martin, Shouten, & Haxby, 1999; Hasson, Harel, Levy & Malach, 2003; and Pietrini, Furey, Ricciardi, Gobbini, Wu, et al. 2003).

Finally, Sergent, Ohta and Macdonald (1992) aimed to investigate the localization of the categorization process, regardless of the specific localization of the categories. They used Living vs. Non Living Things in a categorization task, evidencing left inferior temporal, middle temporal and middle occipital gyri activation, whereas no anterior temporal activation was found.

- Contrary to the modular hypothesis, it has been proposed that the objects are represented through a **distributed pattern of activation** within the ventral stream.

For instance, Haxby, Gobbini, Furey, Ishai, Schouten and Pietrini (2001) proposed that the temporal and the occipital areas are organized on the basis of the object-form. They found that diverse regions respond to specific categories within the

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[10] For similar findings, derived from the neuropsychological investigations, see paragraph 4.2.3.1).

ventral temporal cortex, but that the same areas are activated (even if not maximally) for other objects. They claimed that probably the organization of these regions reflects the way in which complex visual features "[...] *are related visually, structurally, or semantically*".

In the same light, Ishai et al. (1999) investigated whether the objects are represented in category-specific areas or not; moreover, they aimed to test the hypothesis of a widely distributed representation within the ventral visual pathway. Their idea was that if the object representation is feature-based (and not localized in a specific region), then different categories would be associated with diverse patterns of activity in the same cortical area. They presented the subjects with a matching to sample task involving three categories (i.e. houses, chairs and faces) in a fMRI study. Their results showed that these three categories were actually associated with distinct areas of activation within the temporal lobe: the medial fusiform gyrus for the houses, the lateral fusiform gyrus for the face and the inferior temporal gyrus for the chairs.

Despite this high selectivity, some secondary regions were found to be activated during each category presentation, suggesting that a distributed representation can not be excluded. The authors concluded that the temporal cortex "*contains a continuous representation of information about object form*", consistently with the Tanaka's position (1996; see below). They further claimed that a distributed representation of features sustains the object representation, but the most salient features for the category definition are clustered together, so that a specific activation for a single category can be found. In line with Tanaka, they state that the nature of these *clusters* is not known, even if one intriguing possibility is that they consist in what Tanaka refers to as the "*primitives*".

A similar position is taken by Chao, Haxby and Martin (1999), who -in a fMRI study- presented the subjects with a matching task involving the animals', tools', faces' and houses' categories (photographs or written words). Their main result was that the pictures and the nouns associated with the animals' category determined an activation of both the temporal and the occipital areas. In detail, the animals, more than the tools, elicited a greater response in the medial occipital cortex and in the inferior occipital gyrus; moreover, this selectivity was not restricted to the pictures, but it was observed also for the presentation of nouns (thus excluding the visual complexity confounding factor role). They also reported a further differentiation of responses in the fusiform gyrus, with the lateral aspects strongly activated by the faces presentation, and the medial aspects activated by the animals. The authors suggested that the ventral temporal areas are organized in a continuous stream of representations, in which the diverse categories can be represented in discrete areas, with the similar objects clustered, according to their shared shape-features. Finally, they reported that the same areas were activated by the animals-stimuli when the words were presented (instead of the pictures), corroborating the idea that the identification of such category requires the visual features retrieval even in absence of the pictorial input. They concluded claiming that other kinds of semantic information about the animals -stored elsewhere- are gained by the activation of these visual features.

- A third kind of models suggests that the temporal regions are not specialized for specific kinds of material, whereas they are organized according to the type of perceptual information conveyed. For example, Tarr & Gauthier (2000) refuted the hypothesis of a face specialization of the fusiform area, claiming that it is devoted to a more general mechanism for the sub-category processing, in particular in the case of the objects for which we have developed a high degree of expertise.

2.3.5. The Convergence Zones Theory

The "Convergence Zones Theory" (Damasio, 1989, Tranel, Damasio & Damasio, 1997) offers a comprehensive framework for object recognition, based on the assumption of a hierarchical organization of the ventral visual stream. The first step in the process of object recognition corresponds to the depicting of single attributes, which in turn activate the corresponding feature-detectors in the sensory-motor regions. These feature-detectors result in patterns of simultaneous activity, the so-called *feature maps*. The "Convergence zones", correspond to a further step in recognition, in which the simultaneously active neurons are bound in a unique pattern of association. Crucially, their status is not "representational", but they contribute to the creation of the representations, since they mediate the activation of the feature maps, which result (as activation state) in the object representation. In line with this assumption, the actual presence of a bottom-up sensory input is not necessary when a convergence zone is re-activated (by higher level processes), since it can re-activate (through a top-down modulation process) corresponding feature maps. Furthermore, according to the model, the converge zones are organized hierarchically, according to a posterior-to-anterior stream, involving diverse areas of the sensory-motor regions.

In a such a view, an object representation arises from the activation of high level converge zones, in which cross-modality associations are assumed to take place, and require the re-activation of distributed feature maps (as conjunctive neurons) in different brain areas. A fundamental notion in the Damasio's theory is the convergence principle, according to which a unique pattern of activation can be achieved from distributed feature maps and through the mediation of associative processes, resulting in a concept-representation.

2.3.6. Occipito-temporal similarities

Different hypothesis have been advanced with respect to the functional organization of the temporal/occipital cortex (see Grill-Spector, 2003). Converging evidence shows that different areas of the occipital cortex are selectively activated for diverse categories –i.e. faces, houses, animals (i.e. Haxby et al. 2001; Martin, Wiggs, Ungerleider & Haxby, 1996). Ishai, Ungerleider, Martin and Haxby (2000) described a fMRI study, in which they aimed to investigate the functional specialization of the temporal and the occipital cortex for different categories of objects. They presented the subjects with houses, chairs and faces, finding that different areas of the ventral occipital cortex responded to specific categories of knowledge, thus suggesting that both the occipital and the temporal cortices are organized according to a similar topological arrangement. Moreover, each category elicited a stronger activation in a specific area of the ventral occipital cortex plus a secondary activation in other areas, not maximally responding to the same category. This finding corroborated the conclusion of Ishai et al. (1999), that the categories are represented by both a modular organization and a distributed pattern of activation. Ishai et al. (2000), suggested two possible interpretations of these results: (1) the segregation of the representation can occur earlier than in the temporal cortex or (2) the ventral temporal cortex modulates the occipital areas activity (top-down stream of activation), resulting in differential patterns of response.

The idea of a top-down regulation of the occipital cortex by the ventral temporal regions is also corroborated by Martin et al. (1996), who demonstrated in a fMRI study that a top-down modulation is carried out by the temporal regions on the occipital ones. They found specific dissociations within the posterior ventral temporal cortex, elicited by the presentation of different semantic categories (i.e. faces, houses, letters and chairs); moreover, they demonstrated that this specialization had a repercussion on the occipital areas organization. In a development of the same study, Chao et al. (1999; see above) focused on the posterior temporal cortex, instead of the anterior one. In their fMRI study they found an activation of both the temporal cortex (involving the medial fusiform gyrus) and the occipital areas (the medial occipital cortex and the inferior occipital gyrus) in response to the animal stimuli (both pictures and nouns). As previously reported, the authors suggested a continuous representational space within the ventral temporal/occipital areas, in which the clusters of features form representations shared by the category-members.

Interestingly, they suggested that the neuropsychological patients who show semantic deficits restricted to the living things can have a damage to either the animals-specific areas within the temporal cortex or to the feedback-connections from the temporal to the occipital-visual regions. They claimed that "*thinking about a particular object may require activation of the critical features that define that object*"; they further suggested that these features correspond, in the case of the animals, to the visual attributes which allow the fine discrimination between the exemplars of the category. Crucially, this process would involve the feedback modulations of the occipital areas by the temporal regions.

2.3.7. The "special" case of colour information

The issue of colour representation in the brain has received vast interest and convergent evidence comes from different fields, confirming an independent representation of colour from other sensory dimensions (Chao, Weisberg, Wiggs, Haxby, Ungerleider & Martin, 1997).

Different issues concern colour representation in brain. The first is the need to differentiate between colour perception and colour-knowledge retrieval. It is not trivial, in fact, to differentiate between the processes (and the brain areas) involved in the direct perception of object-colour and in the retrieval about the same object-colour knowledge (i.e. seeing that a banana is yellow vs. retrieving the information that a banana is yellow, without seeing it). Martin, Haxby, Lalonde, Wiggs & Ungerleider (1995) took into account this problem in a PET-study (on humans), in which they found that the retrieval of colour words was associated with activity in the ventral temporal (anterior to colour perception). The authors also concluded that the visual attributes which contribute to the object representation are organized in a distributed way, in regions that are anatomically and functionally close to the areas devoted to the perception of the same features. The finding of a separate activation associated with colour perception and colour representations retrieval was replicated in a further study by the same group (Chao & Martin, 1999): the authors used PET on subjects passively watching at coloured or non-coloured objects, and on subjects looking at the same stimuli and required to name the colours or the objects. They found that the colour perception was associated with different areas (i.e. the lingual gyrus/fusiform gyrus of the occipital lobe) than the object-colour retrieval (inferior temporal, parietal and frontal left regions). They also found an occipital activation associated to the object-colour retrieval task, even if they brought evidence suggesting that this specific activation was due to the visual-form processing, more than to colour perception[11]. The main conclusion of their study was that the areas involved in the perception of a feature are not needed in order to activate the representation of the same attribute.

Across the studies bringing evidence in favour of a selective representation of the colour knowledge (vs. colour perception), Zeki & Marini (1988) used fMRI to localize the areas involved in the colour processing, while presenting the subjects with naturally and unnaturally coloured objects and multicoloured scenes. All the stimuli activated the occipital area V4, while only the naturally coloured stimuli elicited an activation of the fusiform gyrus. From this, the authors claimed that the fusiform gyrus, vs. the occipital areas, is specifically involved in the representation of colour-object associations, while the other areas are more generally activated by colour-perception per se.

In a further study, Horel (1996), focused on the contribution of the area TE in colour representation. They reported a series of contrasting studies which showed alternatively a strong involvement of the area TE in colour processing or no contribution of this region in colour representation. They suggested that the area TE would be maybe involved in higher levels of representation, that is, the association of the colour and the form. In other words, the area TE would be useful in object recognition when the colour information becomes crucial for the identification. In his study, Horel presented monkeys with delayed matching to sample tasks, varying the stimuli with respect to the colour-form associations. When the area TE (ventral portion) was suppressed (see Horel, 1996 for details about this procedure), monkeys were not able to perform a delayed matching to sample task. When the dorsal TE was suppressed, the animals resulted unimpaired in simple discrimination tasks and in delayed-matching to sample tasks; on the contrary, they resulted impaired in the retrieval of complex stimuli (association of two features). Despite the fine specialization of TE in object representation, that is discussed elsewhere in this chapter (see paragraphs 2.4.1 and 2.4.2), Horel's study seems to confirm the

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[11] The same areas of the occipital cortex were in fact activated for the non-coloured objects.

contribution of the infero-temporal areas (TE) in colour representation, especially for more than one-attribute stimuli discrimination tasks.

Another problem linked to colour representation concerns the possibility that the areas activated for colour-knowledge are activated by the lexical representations of the colour names, instead of colour-representations. The problem has been ruled out by the evidence that the inferior temporal region is specifically activated for the colour-knowledge retrieval vs. the colour naming, excluding the influence of lexical factors (Howard, R.J., Ffytche, D.H., Barnes, J., McKeefry, D., Ha, Y. et al., 1998). Moreover, in the same study, the areas activated during the colour-knowledge retrieval were also found to be engaged in mental imagery of highly diagnostic-colour objects.

2.3.8. What about texture?

Contrary to the large attention given to colour-knowledge representation, few studies exist about the surface details representation in the temporal cortex.

In one of these, Kovacs et al. (2003) investigated IT selectivity to the surface attributes, presenting monkeys with successive stimuli with decreased complexity (less internal contours, no surface texture and shading etc.). The recording from IT revealed that the neurons specificity for the object-form was not changed by the texture or the shading deprivation, even if their responsiveness was (weakly) influenced by the stimulus manipulation.

In another study, Barrett, Large, Smith, Michie, Karayandis et al. (2001) hypothesised that colour and texture representations could both rely on the occipito-temporal areas, even if their patterns of activation could be different and, in the case of texture, more distributed. In order to test these hypotheses, the authors developed a PET study in which the subjects were required to perform a delayed matching to sample task on an abstract geometrical pattern. Interestingly, the method used allowed to separate the colour and the texture processing, since the task required to alternative pay attention to the colour or to the texture dimension (which were manipulated in different trials) in two separate conditions. The results evidenced common areas of activation for the colour and the pattern processing, involving the occipital and the temporal gyri, and other regions within the parietal lobes. The specific areas of activation associated with the colour-task (left posterior occipito-temporal areas) were considered by the authors as a support to the previous findings about the object and the colour representation (i.e. Zeki & Marini, 1998; Howard et al.

1998); in particular, the idea of a posterior-anterior axis of increasing activation - proportional to the complexity of the stimuli- was confirmed by some PET findings.

With respect to the specific activations for the pattern processing, a bilateral occipital and temporal selectivity was found, in line with the literature showing the fusiform gyrus and the inferotemporal cortex specialization for the complex patterns analysis. Despite the different activations for the two tasks (i.e. colour and pattern task), the subtraction of one from the other gave no significant results. The authors claimed that the same areas (at least the occipital ones) are activated for both the tasks, since the activation derives from the stimulus and not from the required processing (the feature to attend to). On the contrary, some degree of differentiation between the colour and the texture task activations emerged in the temporal cortex, suggesting that these regions are recruited in a task-dependent fashion.

2.4. The perirhinal cortex role in visual memory

2.4.1. The perirhinal cortex

In quite recent years, the perirhinal cortex has received increasing attention as a possible structure involved in visual recognition and memory (Murray, Bachevalier & Mishkin, 1989)[12]. Its anatomical position is quite peculiar, since it is actually part of the medial temporal lobe (it corresponds to Broadmann areas 35-36) but it is functionally in strong communication with the inferior temporal lobe. In detail, the perirhinal cortex receives visual inputs from the areas TE and TEO (Suzuki & Amaral, 1994) and other sensory inputs from the associative regions.

An attempt to differentiate the perirhinal's from the TE's contribution in visual recognition and memory came from Buckley, Gaffan & Murray (1997), which brought evidence in favour of a double dissociation between the perirhinal cortex and the middle temporal gyrus (including TE). In an ablation study on the monkey, these authors showed that both the perirhinal and the TE regions play a role in visual recognition and that they are both recruited in the object knowledge representation.

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[12] It is worth noting that there are studies which show the perirhinal cortex contribution in memory tasks involving different kinds of sensory material. For instance, Parker & Gaffan (1998) demonstrated a role of the rhinal cortex in a flavour-visual association task, corroborating the idea that this region is specialized for general *sensory* (instead of *visual*) association memory. However, the contribution of other sensory channels to the associative memory is not considered here, since this topic eludes from the interests of the present work.

However, they suggested a differential contribution of the two structures, with the perirhinal cortex more involved in the processing of whole-objects or parts of objects, and TE more activated in the processing of single elements and features.

Other studies show that the perirhinal cortex is involved in the formation of stimulus-stimulus associative memories (Murray, Gaffan & Mishkin, 1993). For instance, a specific role of the perirhinal cortex in the object representation was sustained by Buckley & Gaffan (1998), which observed an impaired performance of both a visual associative task and a configurations' learning task (in which learning was rewarded with food) in monkeys with the ablation of the perirhinal cortex. The authors concluded that the perirhinal cortex, which crucially receives strong visual inputs from the areas TE and TEO, is highly specialized for the object knowledge representation, and they further claimed that their findings were in line with the Tanaka's model of a hierarchical organization of the temporal cortex (1996; see paragraph 2.3.2 for details). The authors suggested a differential role of the perirhinal cortex and the area TE, further developing the Buckley et al. (1997) position: while TE was supposed to be devoted to the processing and the representation of the single features of the objects, the perirhinal cortex was thought to allow the binding of these single-information units in more complex representations. Moreover, they also suggested that the perirhinal cortex can put together the visual and the non-visual information about the objects, allowing a full integrated representation of the stimuli.

The same group of research, in a further study (Buckley, Booth, Rolls and Gaffan, 2001) advanced the hypothesis that the perirhinal cortex is actually not specialized for perception or memory per se, but it is involved in more abstract levels of representation. Similarly to Buckley et al. (1997), the authors trained monkeys with the perirhinal ablation in a series of recognition memory tasks, in all of which an odd-stimulus had to be identified. The results evidenced a specific performance-impairment for the ablated animals (vs. the control animals), which were impaired in processing of complex features discriminations. From this, the authors suggested that the perirhinal cortex is involved in abstract-level of processing, at object-level (involving features conjunctions).

Recent studies also re-considered the anatomical connections of the perirhinal cortex with the other temporal regions. For instance, Saleem & Tanaka (1996) focused on the perirhinal and the entorhinal cortices to the area TE. Firstly, they showed that different parts of TE receive diverse input connections from the area TEO; secondly, they evidenced that TE differently contributes to the perirhinal area, since the anterior ventral TE projects to a large area of the perirhinal cortex (about half of the area 36 and the area 35 as well) and to the entorhinal region, while the anterior dorsal TE projects to only a small region within the perirhinal area. The authors suggested two functional interpretations of this anatomical divergence of the perirhinal connections. The first hypothesis is that the perirhinal cortex is maybe receiving visual inputs from the anterior TE, while the dorsal part of TE is projecting other kinds of information to the other cortical regions; the second interpretation is that the perirhinal cortex has two separate parts, specialized according to the kind of input they receive. Despite which of the two alternatives win, the authors evidenced that the anterior ventral TE projects to the perirhinal cortex according to a convergence principle, so that a specific region of the perirhinal area receives from distributed sites of TE. This anatomical organization would be the basis of the supposed role of the perirhinal cortex in associative memory for visual information.

Interestingly, in line with the aforementioned hypothesis of a top-down modulation of the visual occipital areas by the temporal regions (Martin et al. 1996; Chao et al. 1999), Saleem & Tanaka demonstrated the existence of backward connections from TE and TEO to V1 and V2 and, additionally, from the perirhinal cortex to the area TE.

Similar results were shown by other authors, using both single-unit recording techniques and behavioural measurements (involving visual stimuli associative memory tasks) on monkeys with perirhinal ablation (Higuchi & Miyashita, 1996).

Interestingly, Miyashita, Okuno, Tokuyama, Ihara & Nakajiama (1996) demonstrated that the unilateral ablation of the perirhinal cortex is not sufficient in order to disrupt the monkey's visual association abilities. However, when the unilateral perirhinal ablation was associated with the lesion to the inter-hemispheric connections between the anterior IT cortices, impairments in the visual pairs-association task were observed. The authors concluded that the unimpaired perirhinal cortex was still able to sustain associative memory (since there were no deficits for mere unilateral perirhinal ablation), but the impossibility to send backward information to the anterior IT determined visual associative memory deficits.

Taken together all these studies corroborated the Saleem & Tanaka's position (1996), supporting the idea of the perirhinal contribution to associative memory through a backward system of connections to IT.

2.4.2. A hierarchical model of features' representation relying on the perirhinal cortex

A first attempt to clarify the perirhinal cortex role in visual memory came from Murray & Bussey (1999), which reviewed the literature about the rhinal contributions to recognition and storage of visual memories. The authors proposed a tentative model of the ventral stream organization, in which the visual representations are supposed to be organized in a hierarchical way, with the simple features represented in the anterior areas and the complex conjunctions of features in the more posterior regions. They suggested that the perirhinal cortex could be the region in which the conjunctions of features are represented, whereas the more anterior areas (i.e. TE, TEO) could be devoted to the processing of simple features. This position is validated by the anatomy of the ventral stream since -as previously stressed- the areas TE and TEO have a direct connection with the perirhinal cortex.

The same authors commented about the validity to compare the monkey and the human temporal lobes: the problem is not trivial, since actually the largest part of the suggestions about the ventral visual stream organization comes from monkey lesion studies, but the inferences are made with respect to the human cognition as well. They reported a study by Burwell (1996), in which a comparison between the monkey and the human anatomies is carried on, with the conclusion that a similar functional organization of the temporal areas and, in particular, of the perirhinal cortex can be thought for the two species.

Quite recently, the position of Murray & Bussey (1999) has been further specified (Saksida, Bussey & Murray, 2000; Bussey & Saksida; 2002). In detail, Bussey & Saksida (2002) proposed a connectionist model -in an extension of Hubel and Wiesel original model (1962, 1965)-, based on the idea of a hierarchical organization of the visual representations within the temporal areas. The authors built up a simple connectionist network based on the assumption that the simple visual features are represented in the caudal regions of the ventral stream, while the conjunctions of features are stored in the more rostral areas. The model was able to discriminate between similar features and to represent complex visual stimuli. Lesions at the model were created in order to test the hypothesis that the perirhinal cortex is devoted to the feature-conjunctions representations and that it is specialized for the retention (more than for the learning) of associations. Crucially, the single units of the network were not supposed to represent a unique neuron, but a population of interconnected cells, giving rise to a unique representation. The results of the lesion to the network corroborated the idea that the perirhinal cortex is the site of the features' conjunction representation; moreover, the authors showed that the perirhinal cortex is really devoted to the fine discrimination tasks and that it is specialized for retention more than learning. Bussey & Saksida claimed that the utility of a double representation of the features in the temporal regions (as single units and as conjunctions) allows the disambiguation of the similar stimuli, which can be distinguished only on the basis of the fine features.

Other works by the same research group (Bussey & Saksida, 2002; Bussey, Saksida & Murray, 2002) provided convergent evidence that the monkey ventral stream is actually hierarchically organized. These studies, conducted on the monkey, confirmed the results of the connectionist model proposed by Bussey & Saksida (2000), showing that the lesions to monkey's perirhinal cortex actually determine deficits in the visual features discrimination tasks, especially when a high degree of ambiguity is present in the stimuli. Interestingly, according to Bussey, Saksida & Murray (2002), the proposed model of the ventral stream hierarchical organization does not predict a mere visual specialization of the perirhinal cortex. On the contrary, the authors claimed that, since the perirhinal cortex receives input from different sensory stations (i.e. TE for visual information, insula for touch, superior temporal gyrus for auditory inputs), "[...] *It is conceivable that these connections allow the binding of visual and nonvisual features in the service of object identification*".

2.4.3. A comprehensive hypothesis of object representations' organization: Tyler et al. 2004

In a recent work, Tyler et al. (2004) investigated the contribution of the perirhinal and the entorhinal cortex in object processing, aiming to relate the human and the primate findings on this topic. The main aim of the study was to test the hypothesis that the temporal areas are differentially activated, depending on the level of information required by the task. In the authors' view, naming a visually presented object can demand different levels of processing, according to the level of specification required by the task: for example, a donkey can be named at a broad level, as "animal" or at a specific level, as "donkey". Tyler et al. reasoned that different levels of discrimination would rely on diverse areas within the temporal stream, according to recent frameworks of the ventral stream organization, which assume a hierarchical structure of the representations (i.e. Bussey, Saksida & Murray, 2002). In their study, the authors presented the subjects with two kinds of object naming, one involving a domain-level identification (i.e. *animal* for donkey-picture) and one requiring a basic-level discrimination (i.e. *donkey* for donkey-picture). These tasks were employed in both a fMRI investigation on normal subjects, aimed to localize the crucial areas for the object fine-grained processing (the perirhinal and the entorhinal cortices, in particular), and a behavioural investigation on 4 Herpes Simplex Encephalitis patients, who all showed semantic deficits as the consequence of a bilateral medial temporal and rhinal cortex damage. The fMRI study showed that the domain-level naming and the basic-level naming were actually associated with different areas of activation; in detail, the domain-level naming was associated with the bilateral posterior Infero-temporal activity, extending to the fusiform gyrus, while the fine-level naming determined the recruitment of the left antero-medial temporal areas, including the perirhinal and the entorhinal cortex. The neuropsychological data corroborated the evidence of a great involvement of the perirhinal and the entorhinal cortices in object fine discrimination, since all 4 patients resulted impaired in the fine-level naming.

As a conclusion, the authors claimed that their findings brought further evidence in favour of a hierarchical functional organization of the temporal cortex, with the anterior regions more activated for the fine-grained processing of visual objects, in line with other researches (i.e. Damasio, 1989; Bussey et al., 2002). Moreover, in a development of the same study (Moss, Rodd, Stamatakis, Bright & Tyler, 2004), the authors proposed that the specific semantic impairment for the living things, usually occurring in HSE, and following the damage to the antero-medial temporal aspects, can be due to the loss of the distinctive features characterizing this category and by the inability of the patients in processing the fine-grained attributes, which are crucial in order to perform a standard semantic task.

2.5. Conclusion of Chapter 1

2.5.1. Summary and comments

Object recognition has been investigated from different points of view, ranging from the computational perspective to the electrophysiological studies on the monkey brain. The review of the literature evidences some critical points, which are common to all these approaches.

(1) One problem concerns the *nature of object representations*. All approaches assume that recognition process occurs through the matching of the perceived

instances with the stored traces in memory, in order to identify the stimulus or to decide it is a novelty. One related issue concerns the nature of these stored descriptions. The literature review shows that in both the computational and in the neural approaches contrasting models have been suggested: the "holistic" models (single units underling a full object representation) are contrasted by the "distributed" ones, which assume a more sparse activation for the object representation. In detail, within the computational models, the viewpoint-based theories (i.e. Bülthoff & Edelman, 1996) are in contrast with the structural description models (Marr, 1982; Biederman, 1987); on the other hand, the holistic neural representation theories (i.e. Poggio & Edelman, 1990) are in disagreement with the distributed representation models (Pasupathy & Connor, 2001; Tanaka et al., 1991).

(2) The so-called *binding problem* (Treisman, 1999) represents and important issue about object representation, since it introduce the question whether the single attributes of objects are separately processed and (consequently) represented at the structural description level. Obviously, the viewpoint-based and the holistic theories do not need an explanation of binding, since they do not expect the single features/object's parts to be separately considered. Attempts to solve the binding problem come from the distributed models, which assume an independent representation of the different object's parts and the details. Interestingly, the most complete solutions (see Hummel & Stankiewicz, 1998) suggest a sort of "two-route" model for object recognition, in which both a holistic processing (for the novel instances) and an active attentive binding (for the well-known stimuli) are allowed.

(3) The idea of a "double" kind of reconstruction is in line with the neural literature, in which the apparent controversial findings of *holistic, "shapes-prototype" representation of objects* (i.e. Poggio & Edelman, 1990) vs. *distributed activation* for single aspects (i.e. Tanaka & Taylor, 1991: Sughiara et al., 1998) is solved by more comprehensive models of the infero-temporal cortex organization. Interestingly, Baker et al. (2002) proposes a solution that resembles the "double-route" approaches to the binding problem, since he suggested a different kind of activation in IT for the complex and the well-known stimuli (distributed vs. holistic activity, respectively). However, Hummel & Stankiewicz (1998) proposes a holistic processing for the novel objects, while Baker et al. (2002) suggest that a holistic representation underlies the well-known stimuli processing; it is worth noting that the binding problem usually refers to the perceptual processes, while the neural models concern higher levels of representation. It is possible that the cognitive system uses different strategies

according to the task demands and to the stored resources allowable. In the perceptual binding, when an object is firstly encountered, it has to be perceived as a unique entity, since the lack of an underling structural description in memory determines the needing of a global perception. On the contrary, in the high level object representation, the novel entities have to be carefully evaluated, requiring complex processes of storage of the single elements; the well-known instances do not need such a detailed analysis, since they have a "preferential" route, bringing directly to a stored structural description.

(4) From an anatomical point of view, converging evidence identifies in *IT the region devoted in object representation*. Quite interestingly, this area has been shown to resemble the occipital cortex organization: several evidences exist in favour of strict similarities and connections between IT and V1-v4, in both a bottom-up and a top-down direction (Martin et al., 1996; Chao et al. 1999; Ishai et al. 2000). The Tanaka's model of object representation within the temporal stream (1996), for example, proposes a columnar organization of the representations, in which the single neural units are activated for specific material and the distributed patterns of activation contribute to the full object representation. In such a model, it is possible to imagine both a prototype-representation, for small loops of interconnectivity between the neuronal units, and larger and sparse distributed activation patterns underling the more complex and complete object representations.

Crucially, this model fits with large part of the physiological and the imaging findings on both the human and the monkey, evidencing a specialization within IT (area TE) for the visual memory and the object representation (i.e. Kovacs et al. 2003; Tsunoda et al. 2001; Wang et al. 2000).

(5) Recent investigations have further specified a strong contribution of the *perirhinal cortex in memory for feature-conjunctions* (Buckley et al., 1997). The derived connectionist model (Bussey & Saksida, 2002) proposes a hierarchical organization of IT, in line with the previously cited columnar organization suggested by Tanaka (1996). This kind of model fits with other (more computational) models of the infero-temporal cortex organization, such as the Convergence Zones Theory of Damasio (1989) and recent suggestions by Tyler et al. (2004). All these models assume a stream of activation underlying object recognition, with increasing in the complexity of the representations going from the posterior areas (occipital, TEO) to the more anterior regions (including perirhinal cortex and TE). These models assume

that the single features can be stored separately (posterior); however, the feature-conjunctions are represented as complex entities in the anterior areas.

(6) A further issue linked to object representation concerns the possibility that the categories of similar objects are represented as modules within the brain (Caramazza & Shelton, 1998). A similar idea is sustained by studies which report a specialization of particular areas within the temporal stream for certain important classes of stimuli, such as the animals (Damasio et. al 1996; Hasson et al. 2003) and the faces (Grill-Spector et al. 2004). Alternatively, it has been proposed that the categories result from a distributed pattern of activation (Haxby et al. 2001; Ishai et al. 1999; Chao et al. 1999). As in the case of the single object representation, a conciliation of both the theories appears not impossible, in particular in light of recent models about the ventral stream organization (Tanaka, 1996; Bussey & Saksida, 2002; Tyler et al. 2004).

(7) The aforementioned models about memory for feature-conjunctions take into account the issue of single *visual features* in a more specific way than the general models of object recognition. The main problem related to the visual features concerns their status in memory (are they separately represented?), the format of the possible representation (pictorial vs. verbal) and the relationship with the structural descriptions, which are usually defined as form-descriptions. We reported studies on the colour contribution on the shape processing (and vice versa, in some cases), which come to partially different conclusions. From a general point of view, the imaging studies have demonstrated a separate representation of colour from other sensory information (Chao et al., 1997), and the ventral temporal areas have been shown to be activated in tasks of colour-knowledge retrieval (i.e. Martin et al., 1995; Chao & Martin, 1999); moreover, the specific areas involved in object recognition seem to be recruited also in the colour knowledge processing (area TE; Horel et al. 1996). Fewer studies exist focusing on the object-texture knowledge representation; however, some of them bring evidence in favour of a representation relying on the ventral temporal areas, even if the texture appears as a more distributed and weaker representation than the colour (see Kovacs et al. 2003; Barrett et al. 2001).

With respect to the models of object recognition, a clear-cut division can be operated, since some theories reject the possibility of the visual feaures' contribution in object recognition (Biederman & Ju, 1988), while other models (deriving from Marr, 1982) give them an active role in the object re-construction and identification.

We reported a series of studies focusing on the role of the colour in the object-shape processing, which come to partially different results. Some studies (using coloured and black and white stimuli in different tasks) have shown that the task requirements -in terms of the level of discrimination required- and the material properties (i.e. the similarity between items) can modulate the colour contribution to object recognition (Price & Humphreys, 1989). Moreover, Ostergaard & Davidoff (1985) sustain a differential contribution of colour in pre-semantic and semantic tasks (classification and naming, respectively), suggesting an abstract representation of colour in memory. Other studies come to contrasting conclusions about the relation between colour and shape. We reported studies concluding that the processing of the object colour is impossible without the shape-mediation (Naor-Raz et al. 2003; Walker & Cuthbert, 1998), and others claiming a separate representation of the two dimensions in memory (Hanna & Remington, 1996). Further studies suggest alternatively an automatic integration of colour and shape in a unique representation, or a separate representation of them, in a frame of strong connections between the two (Nicholson & Humphrey, 2003).

2.5.2. Conclusions

Two different points of view dominate the object recognition literature: the objects are stored as unique entities in the brain vs. there is a distributed representation, in which the different parts/details can be separately represented and re-activated for the object processing and identification. Despite the general conflict between these two ideas, several studies here reported suggest a possible conciliation between these positions. The more recent and comprehensive models, in which both the structural and the functional organization of the temporal cortex are considered (Damasio, 1989; Bussey et al. 2003; Tyler et al. 2004), speak in favour of a distributed representation of the objects in the ventral cortex, with the single aspects stored in the posterior areas and the complex conjunctions in the anterior regions, even if they do not rule out the possibility of a categorical organization, resulting from the simultaneous firing of complex patterns of activity. Crucially, these models consider the possibility of a separate representation of the visual features.

We are interested in further investigate the possible independent representation of such surface features, at least in the case of diagnostic-surface objects- (i.e. animals, fruits), focusing more strongly on these aspects. All the reported studies, in fact, usually manipulate the colour presence within a picture, or deprive the stimuli of the visual information in successive presentations, looking at areas of activation in the brain, or at the behavioural performance of the subjects. In only few studies (i.e. Walker & Cuthbert, 1998; Ostergaard & Davidoff, 1985; Barrett et al. 2001), such features were critically presented outside the relative shapes, as backgrounds or patches. These studies, anyhow, do not focus on the specific representation of these aspects, but on the relationship of them with the shape. We are interested in a similar issue, but we will focus more directly to the question whether such features *alone* can have a representational status. In other words: assuming a functional organization of the ventral cortex as suggested by Tyler et al. (2004), can we think that a surface detail, such as a skin of fruit, conveying no shape information, can directly activate the concept-representations? And, more in general: are the surface details and the shape-information stored and represented separately, with an independent (but overlapping) semantic status?

3. Experimental part: Healthy subjects' study

3.1. Introduction

3.1.1. Open questions about visual features' representations

Evidences coming from different areas seem to support the idea of a specific representation of the colour and the texture features in the occipito-temporal stream (see Chapter 2); however, some questions regarding the nature of such representations and the relation of such information with the object-shape representation remain still under debate.

The main aim of the healthy subjects' studies is to investigate the contribution of the surface features in object representation. In detail, we considered three topics.

(1) We would like to investigate whether the surface features can contribute in the activation of the specific visual representations of the objects[13].

This has been done in two ways. First of all, since we were interested in the surface features role in object representation, we selected two classes of objects which are strongly defined by the surface features –i.e. the fruit and vegetables and the animals-. It has been suggested that for some categories of objects (i.e. fruits and vegetables) the specific visual information can be determinant in order to distinguish among different exemplars of the class (i.e. Warrington and McCarthy, 1987).

Secondly, following the reasoning of Price & Humphreys (1989) and Tyler et al. (2004), we decided to vary the task requirements, but using the same material. Thus, we used an Object Decision Task (requiring a fine-discrimination of the targets, see paragraph 3.3), a Categorization Task (requiring a semantic classification of the stimuli, see paragraph 3.4), and different kinds of Word Categorization (assumed to activate cross-modal representations, see 3.5, 3.6 and 3.7). The comparison between the different tasks performed on the same material allowed us to make inferences about the kind of representations activated in each experiment (i.e. shape-representation or fine details?).

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[13] Notice that we are not speaking about *perception*, but about *memory* for the object characteristics.

(2) A second aim of the experiments was to see whether the surface features can be activated independently from the shape dimension.

All the experiments presented in this chapter use the same basic paradigm: a picture depicting the surface characteristic of the fruits, the vegetables and the animals, where no information about the shape was given (i.e. a squared patch –see later, Figure 5) was used to prime a shape or a word (representing a fruit, a vegetable or an animal, respectively). This allowed us to specifically test the possibility that the surface features, presented without a co-occurring shape, can be recognized as part of an object and can activate other representations corresponding to the same object.

(3) A further aim was to investigate the nature of the surface features' representations: are they part of the structural descriptions[14], or can they be considered as *semantic* information?

Even if priming effects are found -suggesting that the surface features contribute to the object representation-, we can not exclude that they are due to the pre-semantic activation of refined structural description representations.

A way to rule out this possibility is to compare the effect of the primes matching the target (i.e. the surface feature corresponding to the following target-object) with the effect of the primes which do not match the target, but one of its category neighbours. In other words, if we find an effect (of facilitation or interference) of a prime that is semantically linked to the target, but not corresponding to it, we can infer that the prime has been processed at the semantic level.

3.2. Hypothesis about object recognition and representation: what about the visual surface features?

3.2.1. General considerations

In Chapter 2, we presented a series of models, derived from the Marr's theory of object recognition (1982), in which the visual system processes the objects starting from the parts and the components, it compares them with the stored representations, until achieving a complete object representation, the so-called

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[14] Or, alternatively: are the surface features represented like the Structural Description but independently from it (similar to it with respect to the representation nature, but stored separately from it)?

"structural description" (e.g. Biederman, 1987; Dickerson et al. 1992). The activation of the Structural Description is needed in order to access the abstract meaning and to subsequently activate the word form (the lexical and the phonological representations corresponding to that concept).

It is worth noting that we are not interested in the first stages of the object-parsing and the re-construction of a complete object representation, nor do we want to focus on the stage of the lexical and the phonological retrieval. Instead, we are interested in understanding how the details and other kinds of visual information[15] about the objects' aspect are represented. In other words, we would like to understand if the specific visual information is part of a general structural description, or if it is stored as a separate "module" that can be activated independently from the global shape.

3.2.2. A tentative model

The two diagrams reported in Figure 3 aim to reconstruct the different types of representation of an object (they are identical, with the exception of the way in which the semantic memory store is intended -see later in the text). Starting from the visual input object (i.e. a picture representing a *tiger*), the early visual processing allows the identification of the gross structure, resembling the "animal-like" shape. The further steps in the analysis of the shape dimension would involve the recognition of the parts and the details of the object (i.e. ears, tail etc.), the re-construction of the complete structural description (a tiger-like shape, including the proportions, the parts, the surface gross details) and the adding of the specific and more elaborate details, maybe not necessary for the item identification (i.e. claws).

Reasonably, a specific processing of the surface details takes place at the early stages of object analysis -and possibly in parallel to the shape analysis-.

It is worth noting that the different stages of the activation are intended to resemble the visual analysis during object recognition (by the visual input) AND the corresponding activation of matching representations in memory. In other words, when seeing a tiger, the activation of the representations about the gross shape, the parts, the structural description would occur from the memory store. Similarly, the specific analysis of the surface features, like colour and texture, is likely to activate

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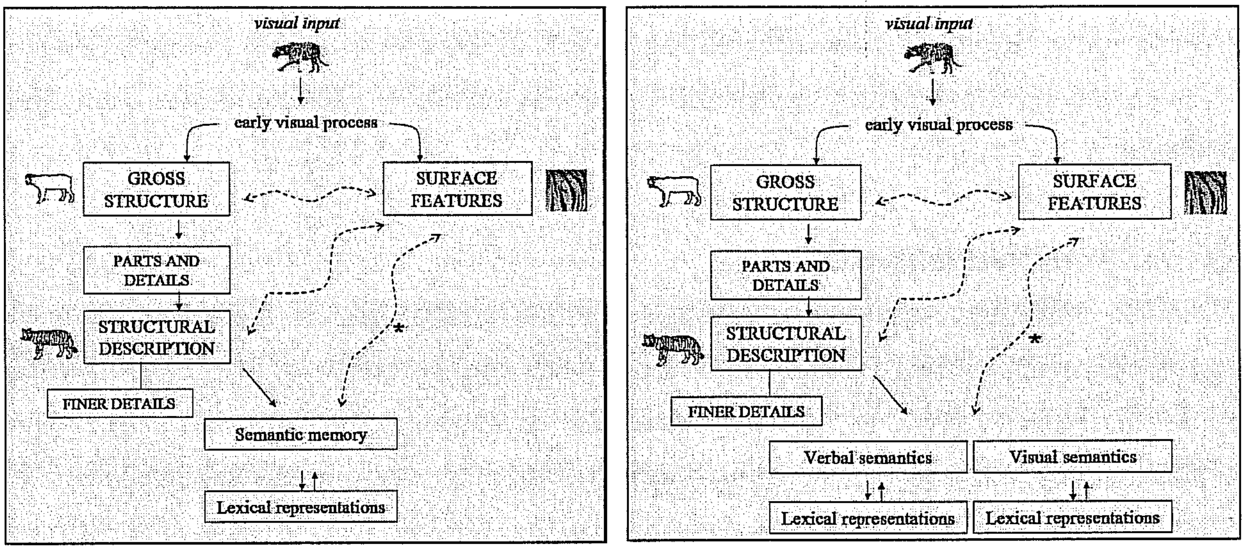
[15] With "specific visual information" we would refer to the visual features different from the global shape and the other form-characteristics needed for recognition.

the corresponding representations in memory (i.e., in the case of a tiger, the black-and-yellow striped fur).

The final step would be the activation of the semantic knowledge. Part A and B of Figure 3 represent two possible alternative diagrams resulting from assuming a unitary semantic memory (in line with Caramazza, Hillis, Rapp & Romani, 1990) or a fractionated semantic memory (visual vs. verbal information: Beauvois (1982), Warrington & Shallice (1979) –but see Chapter 4 for more references).



A - **- B -**

Figure 3. Two possible models of visual object recognition and activation of representations from memory. In A the semantic memory is supposed to be an unitary system, in B semantics are supposed to be fractionated in verbal and visual stores. See text for details.

As previously said (see 3.1.1), our first aim is to investigate whether the surface features can contribute to the object representation: the question, reformulated in terms of the suggested model, concerns whether the "Surface Features" component represents a visual processing stage only, or if it corresponds to the stored information in memory.

A second aim is to understand in detail the kind of relationship between the shape-representations (Structural Description), which are usually thought to be pre-semantic in nature (see Humphreys and Riddoch, 1987), and the other visual aspects, such as the finer details of the shape (i.e. ear form, claws, etc) and the surface features (i.e. black-and-yellow fur detail). In other words, is this information represented separately from the "shape"?

More specifically -and referring to the third aim of the study-, is it possible to activate the semantic information directly from the visual surface features representations, without the activation of the shape-representations? If there is a visual semantic memory (the knowledge about the colour, the fine characteristics of surface etc.) separate from the verbal information (i.e. encyclopaedic information about things, associative information etc.), it is reasonable to expect a direct activation of such store from the surface features, quite independently from both the shape-representations and the abstract-verbal information associated to the object.

However, we cannot exclude the possibility that the visual features are processed early and than they are integrated at a pre-semantic level with the shape representations (structural descriptions).

This question is formalized by the dot arrows represented in the diagrams: if the surface features have of necessity to be integrated with the structural descriptions (or other earlier representations, such as the Gross Structure), the different aspects would interact with the dot lines represented without *. On the other hand, if the surface features can activate their corresponding representations in memory, it reasonable to think that a direct link (dot line *) between them and the semantics (intended as unitary or fractioned) would exist.

3.2.3. Predictions and testing predictions

3.2.3.1. Predictions

If the early processing of the visual characteristics of the object can activate specific memory representations, and these representations are independent of the structural description (they do not need the structural description mediation and they can have a semantic correspondent representation),

- **(a)** ...we would expect a specific effect of the surface features' presentation on the tasks requiring the semantic processing of the items (vs. structural description processing only);
- **(b)** ...the surface features would also have a different weight in defining the diverse categories of objects, in line with Warrington and McCarthy, (1987).

3.2.3.2. Testing the predictions in the study

(a) As previously anticipated, we developed a series of priming studies (involving two specific categories of objects), in which the surface features primed some picture items or words. The tasks were chosen in light of the tentative model proposed in Figure 3. In detail, we assumed that a semantic **Object Categorization** task would rely on different modules when the task requires the classification of stimuli in different semantic classes (i.e. tools vs. animals) and when the task requires an intra-category discrimination (i.e. to distinguish between the domestic and the wild animals), respectively. In the first case, the classification can be performed using basic visual information, possibly localized in what we called "Gross Structure" module: for instance, the gross shape representation of a tiger (see Figure 3) is sufficient in order to identify it as an animal, and to distinguish it from a tool. On the other hand, an intra-category classification requires the activation of Structural Description, in order to identify the item and to activate the associated semantic information (Semantic Memory) required succeeding the task.

In the case of the **Word Categorization Task** we expect the semantic-verbal Knowledge to be firstly activated (through the lexical-semantic pathways), while the Structural Description and the other visual aspects can be activated only in a second phase, as the result of the spreading of activation from the abstract knowledge to the other levels of representation.

Finally, we suggest that the Structural Description component can be sufficient in order for an **Object Decision** to succeed. In this case the task requires one to decide on the reality of an object.

(b) Considering the possible differential effect of the visual features on the diverse categories, we included in the study two different categories of objects –the Fruit and Vegetables and the Animals, respectively-. In line with Warrington and McCarthy (1987), we would expect the two categories to behave differently, since the Fruits and Vegetables' elements are defined by their surface aspects more than the Animals. In detail, the Fruits and Vegetables are usually quite similar with respect to the shape (i.e. an apricot and an apple are both rounded), while they have different surface-surface features (i.e. an apricot is orange-coloured and slightly hairy, while an apple is usually smooth and red). On the other hand, the animals can be easily differentiated on the basis of the shape-details (i.e. elephant has big nose and ears, while giraffe has a long neck) and also by surface details (elephant is grey, while giraffe is yellow and brown). Crucially -and differently from the Fruits and Vegetables- it is very easy to recognize the animals from their shape, even if surface features are not available.

Thus, we would expect differential effects of the surface features used as primes on the two categories of objects: in detail, there should be more effect of the primes on the Fruit and Vegetables than on the Animals.

3.3. Experiment 1: Object Decision

3.3.1. Specific aim of the experiment and predictions

Experiment 1 aims to investigate the possible contribution of the visual surface details (used as primes) when the target-shapes have to be analysed in a fine way.

The possible effect of priming determined by the surface features presentation (used as primes) would be interpreted as the contribution of such features in the object visual representation. As previously suggested, an Object Decision Task is supposed to rely on the Structural Description activation, without necessarily involving the semantic representations. Thus, if we find a priming effect only in the case of matching between the prime and the target (what we will call the "Identity Prime", see 3.3.2), we could not exclude that this effect is pre-semantic, and associated to the perceptual representations of the object. However, the possible existence of a facilitation attributable to the primes not corresponding to the target, but semantically related (i.e. a surface aspect belonging to an object from the same category of the target: what we will call "Same Category Prime", see 3.3.2), would be interpreted as a "semantic" effect of the primes. This would mean that the primes are not treated as part of the Structural Descriptions only, but that they are able to activate the abstract information about the category of the object they correspond to.

The effect of primes not matching with the target can be also interpreted as an evidence in favour of the independent representation of the surface features from the shape. In fact, whereas the Identity Prime effect would occur because of the co-occurrence of the surface feature and the shape at the perceptual level (due to the fast presentation of the events in the priming study), this is not possible in the case of the primes different from the Identity. For these primes, in fact, the surface features do not correspond to the following target, and this rules out the possibility of a perceptual binding. In other words, for the primes different from the Identity, the possible effects would be due to activation of the conceptual representations independently from the shape mediation.

When considering the second specific prediction derived from the diagram previously proposed (see 3.2.3.1), we reasoned that the two categories employed in the study (i.e. the fruits/vegetables and the animals) would behave in a similar way, since they can be both considered as the *structurally similar* categories (Price and Humphreys, 1989; Tyler et al. 2004). However, we anticipate here that the object decision task used[16] (see later) would maybe necessitate a differential kind of processing for the two categories, so that deciding about the correctness of a fruit shape would require the activation of fine visual representations (including the colour and the surface features), whereas deciding if an animal form is real or not would just require the structural description analysis (in other words, the animals can be treated as a *structurally dissimilar category* -see 3.3.4 for more details-).

3.3.2. Methods

Subjects

20 undergraduate students (F=12; mean age=25+/-2.7) were recruited from a list of volunteers and paid for their collaboration in the study. All the subjects ran both conditions in the same order. None of the subjects presented visual problems (slight problems were allowed if corrected).

Materials

Items 13 Fruits/Vegetables (8 fruits and 5 vegetables) and 14 Animals (8 exotic and 6 European animals) were used in the first and the second condition, respectively (see Appendix A for details).

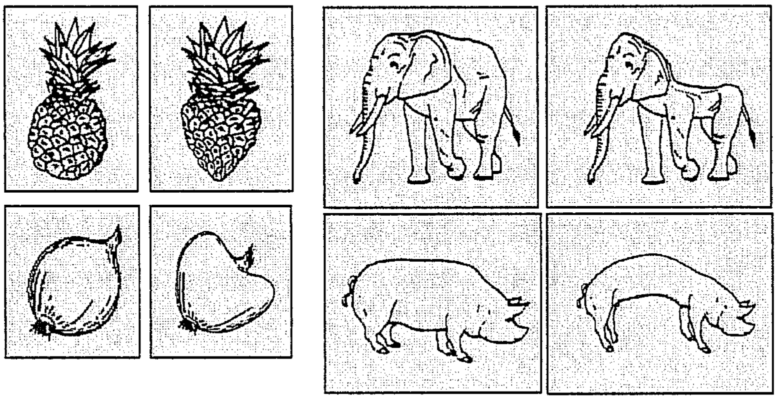


Figure 4. Examples of Targets. On the left of each frame: original pictures for *pineapple, onion, elephant and pig*; on the right of each frame: the manipulated line-drawings corresponding to original pictures.

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[16] The Unreal targets were not chimeras, but real objects modified in their proportions and their details.

Targets The target pictures represented all the items (Fruits/Vegetables and Animals) and consisted in line drawings conveying no colour information and only very general texture details. Part of the pictures belonged to the Snodgrass & Vanderwart set (1981), while other line drawings were directly obtained from free web sites. The pictures were presented in their original appearance, or they were modified with respect to the shape, through use of the Corel-Draw program©[17] (Figure 4).

In detail, we changed the gross proportions of the object parts so that, for example, the *elephant* became very thin and the *pineapple* assumed a more triangle-like shape. All the pictures (the original and the modified ones) were resized, respecting their proportions, in order to be comparable in terms of the dimensions; the line drawings were put in the centre of a white rectangular background, sized 315X300 pixels. Both the original and the manipulated line drawings were presented as targets in the Object Decision Task. An exhaustive list of the Targets employed in the study can be found in the Appendix A.

Primes The primes consisted of squared-pictures depicting the coloured external surface of the same items used as targets or the detail of some other category object (e.g. materials, textiles). For each target-item, four different primes were built, labelled as *Identity*, *Same Category*, *Different Category* and *Baseline* Prime, respectively (see Figure 5).

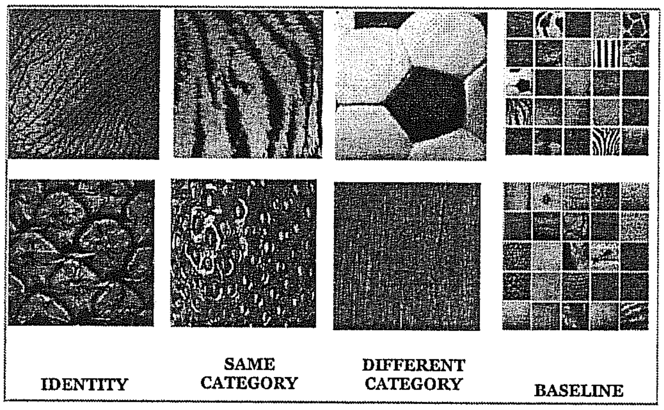

Figure 5. Examples of primes used for *elephant* and *pineapple* items (first and second row, respectively).

The "Identity" prime consisted in the external surface detail of the target picture; for instance, the detail of the *elephant* skin was used as the "identity prime" for the *elephant* target and, in the same way, a picture depicting the *pineapple* skin was used

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[17] Corel-Draw ©

as the "identity prime" for the *pineapple* target. The "Same Category" prime consisted in the surface details belonging to the items taken from the same category of the target, but not matching the target itself: for example, the skin of the *tiger* was used to prime the *elephant* target and the skin of the *strawberry* was used in the case of the *pineapple*. In order to obtain a "Different Category" prime for each item, we built up pictures depicting the details of the objects taken from different semantic arrays: for example, for the *elephant* we used a football ball detail, while in the case of the *pineapple*, the Different Category prime consisted in a green leaf surface. The "Baseline" prime consisted in a picture containing all the prime pictures previously described. All the primes were arranged in a random disposition in a unique square picture. In this way, the baseline matched the other primes employed in the study for the visual information conveyed.

With respect to the "Different Category" primes, we decided to use the details taken from items different from both the sub-categories employed in the two conditions. This was done because we were not interested in seeing the role of the surface features in distinguishing between the two sub-classes (i.e. fruits vs. vegetables) but we were interested in seeing if these visual features could play a role in activating specific concepts and the general class-knowledge.

Thus, we assume the distinction between the fruits and the vegetables (and between the European and the exotic animals) is not dependent on the visual features: for instance, the *watermelon* and the *cucumber* belong to two opposite sub-classes, but they share the visual surface characteristics (same kind of green colour). This means that one must know that the watermelon is a fruit and that the cucumber is a vegetable, and that this kind of information is independent of the external surface information; indeed, the only way to use the skin-properties to classify these objects according to the sub-categories is activating the abstract-verbal knowledge[18].

If a vegetable skin is used as the "Different Category" prime for a fruit, we could not rule out the possibility that it activates both the fruits and the vegetables items,

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[18] Snodgrass & McCollough (1986) discussed the issue of category similarity, claiming that the structural similarity between the category items can be the reason why the pictures are categorized faster than the words. Contrary to that study, the task used here requires a categorization not merely based on the gross physical characteristics; in their view, such a task would not be dependent on the visual judgments only and would not bypass the semantic memory. Moreover, our task-choice is corroborated by Snodgrass (1984), who showed that the picture superiority in categorization is strictly dependent on the visual similarity of the criterion (e.g. fruits/veg or fruit/animal –see Snodgrass & McCullough, 1986, for details).

without determining specific intra-category effects, since both the fruits and the vegetables often result similar in their surface details. In other words, such a "Different Category" prime would behave as a Same Category prime.

Each Different Category Prime was built in order to correspond to one "Identity" prime, so that, for example, the "Different Category" prime of the *elephant* corresponded to the skin of another animal used in the experiment, i.e. *cow* skin, while the "Different Category" prime of the *pineapple* corresponded to the *cucumber* skin (see Figure 5). The complete list of the matched primes and targets is reported in the Appendix A). Each prime picture consisted in a 145x145 pixels (0.61x0.61 cm) square, set in the centre of a rectangular white background, sized 315x300 pixels.

Procedure

The subjects sit in front of the computer in a silent and well-illuminated room, with their index fingers on the response key buttons (keyboard "*c*" and "*m*" buttons). For half of the subjects "*c*" button corresponded to "*real*" answer (see later), for the other half "*c*" corresponded to "*unreal*" answer (notice that handedness was considered in the attribution of participants to one or the other group). The pictures appeared in the centre of the computer screen, through an E-prime Study[19].

Sequence of events The sequence of events is reported in Figure 6.

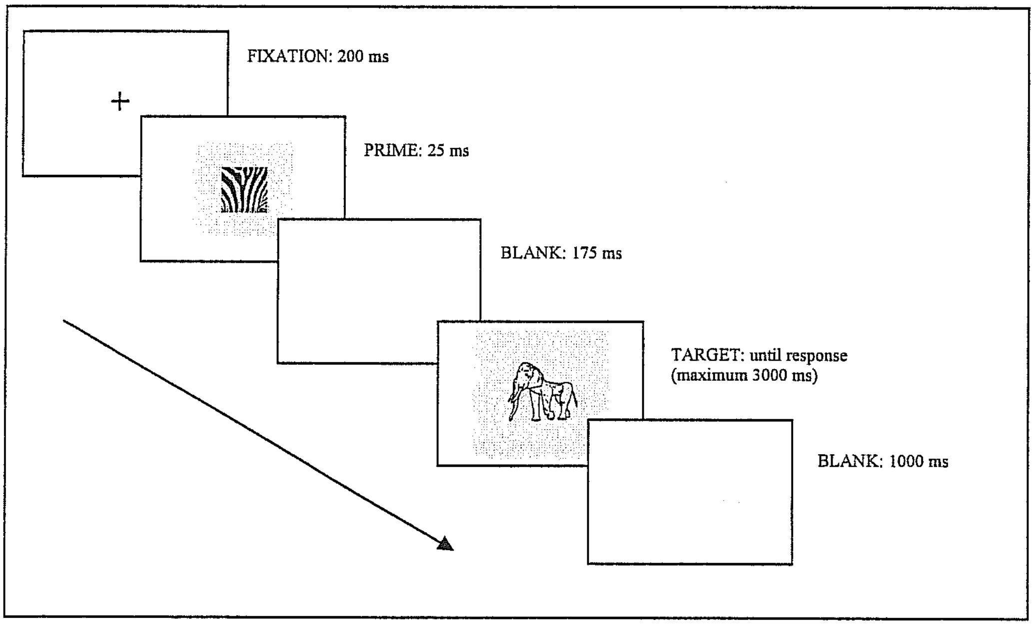

Figure 6. The Object Decision sequence of events.

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[19] E-Prime 1.1 (SP3) ©1996-2003 Psychology Software Tools.

A fixation (1cmX1cm black cross, set in the exact centre of a white background) appeared on the screen, lasting 200 ms; after that, the Prime appeared, lasting 25 ms, followed by a blank (duration: 175 ms). The target appeared immediately after the blank and remained on the screen until the response was given, with a time-limit of 3000 ms (after which it disappeared). The ITI (inter-trials-interval) was 1000 ms. The ISI was 1200 ms and the SOA was 200 ms.

Conditions and trials All the subjects ran both the conditions in the same order (Fruits/Vegetables first, then the Animals). The two conditions implied the same task and the identical procedure. For each category, the total number of the trials corresponded to the doubled number of items (each item appeared once in its original form and once in its manipulated appearance), multiplied by the number of the possible primes. In this way, the subjects were presented with 104 trials for the Fruits and Vegetables condition (13 items, each presented twice, for the correct and the incorrect shape, and in association with the 4 possible primes). Similarly, in the Animals condition the subjects were presented with 112 trials (corresponding to the 14 original items). During each condition, a break was provided after 50% of the trials.

Task

The subjects were instructed to pay attention to the shape of the line drawings, which would appear on the computer screen one after the other. They were explicitly told that the experimenter had previously manipulated some of those pictures, so that part of the line-drawings actually represented an unreal object. They were asked to decide about the reality of the objects as accurately and rapidly as possible, pressing one of the two button keys on the keyboard. In order to quick up and to render more accurate the subjects' responses, written labels were put near the key buttons, reminding the meaning of them (*real* vs. *unreal*). In general, in both the conditions half of the trials expected a "*real*" answer and half an "*unreal*" answer.

Before starting the testing phase of each condition, the subjects were presented with a practice (in which all the targets were presented once without the prime) in order to familiarize them with the modified pictures. The participants were required to perform the same task used in the test-phase, and no feedback about the performance was given during the practice.

3.3.3. Results

In this and in the following experiments (see 3.4, 3.5, 3.6 and 3.7), the accuracy and the reaction times were collected during the subjects' performance. For each condition a general accuracy mean was calculated, averaging all the trials responses and the same was done for the reaction times. The trials were sub-divided according to the Prime type so that different measures, in terms of both the accuracy and the RTs were obtained for the Identity, the Same Category, the Different Category and the Baseline primes trials (see the Appendix B-Table a). The same procedure was used then, when the data was analysed for the Real and the Unreal Targets separately. For each subject the data was cleaned, excluding from the analysis the incorrect trials and the latencies more/less than +/-2 standard deviations from the general RT mean. The same procedure was adopted for both the conditions.

The statistical analysis was performed following a hierarchical schema, in order to answer different questions without the problem of multiple comparisons on the same data occurring. After checking the presence of a priming effect (Friedman Test), we investigated whether the Identity prime differed from the other primes (Wilcoxon Matched-Pairs Signed-Ranks Test, contrasting the Identity Prime vs. [Baseline + Same Category + Different Category[20]]. The existence of such a difference would mean that the Identity Prime was differently contributing to the general priming effect.

In order to exclude that the difference between the Identity and the other primes was due to a Baseline effect, we compared the Baseline vs. [Same Category + Different Category[21]].

In the case in which the Baseline differed from the Same + Different Category, we further explored the role of the Same Category and the Different Category primes, contrasting the Identity prime vs. the Baseline and the Identity prime vs. [Same Category + Different Category]. Moreover, in order to investigate the possible existence of within-category effects, we contrasted the Same Category and the Different Category Primes directly (where a difference between the Identity and them was found) and, where a difference emerged, we compared the Identity vs. the Same Category and vs. the Different Category prime and, in turn, the Baseline vs. the Same Category and vs. the Different Category prime.

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[20] The four primes were weighted as a general average.

[21] The two primes were weighted as a general average.

If the Baseline did differ from the Same + Different Category primes, we interpreted the effect of the Identity Prime as due to a Baseline (or other primes) effect; on the contrary, if the Baseline did not differ from the Same + Different Category primes, we concluded that the Identity effect was pure.

With respect to the *Fruits and Vegetables* (see Figure 7), a main effect of Prime was found (Friedman Test, *df*=3, χ^2=12.12; p<.01). The latencies associated with the Identity prime were significantly faster than those associated with all the other primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.7; p<.01). No differences emerged when comparing the Baseline with the Same Category and the Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.16; p=.25, *n.s.*) or when contrasting the Same Category and the Different Category primes directly (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.93; p=.35, *n.s.*).

The statistical analysis failed to reveal a main effect of Prime in the *Animals* condition (Friedman Test, *df*=3, χ^2=1.14; p=.77, n.s.).

When comparing the two categories, there were no differences between the Fruits and Vegetables and the Animals in terms of latencies (Wilcoxon Matched-Pairs Signed Test: *df*=1, z=-1.23; p=.22, *n.s.*); however, the accuracy (before data cleaning) was lower for the Fruits and Vegetables than the Animals (T-test, *df*=19, t=4.97; p<.001) (see Appendix B-Table a).

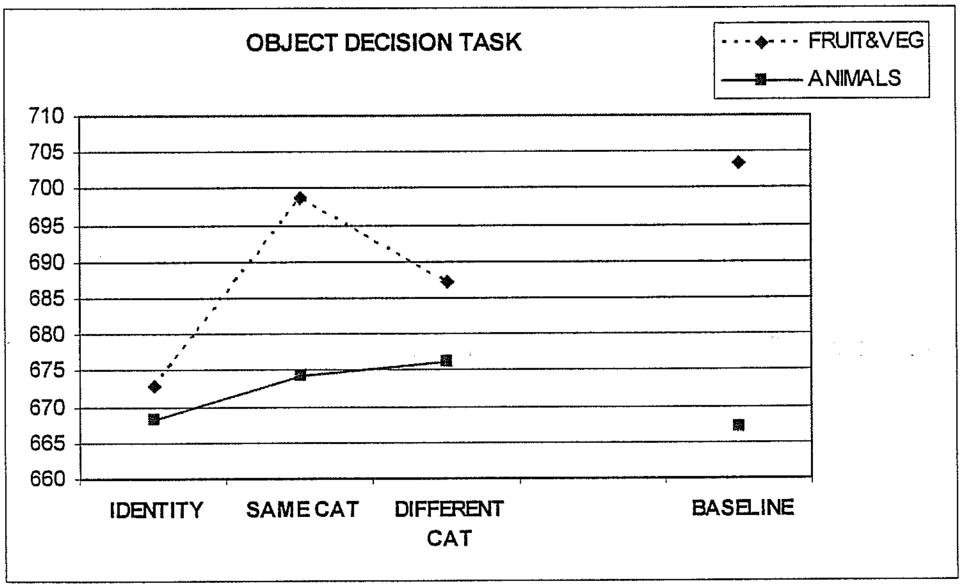

Figure 7. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

Real vs. Unreal Targets

The standard object decision tasks usually employ chimeras –i.e. unreal objects created melding two real ones-. In our experiment we decided to use a different kind of targets, in which finer manipulations of the pictures were carried out, with the aim to activate a "later stage" of elaboration of the pictures (see 3.3.1). We assume this "later stage" relies on the Structural Descriptions and to some further level of representation (i.e. involving semantic information). If different representations are activated in order to solve a standard object decision and our "new" task, respectively, it is reasonable to expect that the subjects would perform differently according to the type of target they are processing –i.e. Real vs. Unreal targets, since the latter stimuli are supposed to be more difficult to analyse.

Following the above reasoning, we would expect differences in terms of latencies and accuracy for the Real and the Unreal Targets. A complete overlap between the Fruit and Vegetables and the Animals occurred in the case of Real Targets, and a quite similar pattern of results to them both was found for the Animals-Unreal targets (see Figure 8). A dramatic change, in terms of slowing of latencies, occurred for the Fruits and Vegetables when the Unreal targets have to be analysed: the statistical analysis revealed a significant difference between the Real and the Unreal Targets for the Fruits and Vegetables (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.91; p<.01), whereas the difference failed to reach significance in the case of the Animals (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=1.90; p=.06, trend).

When each prime was considered separately within the Fruits and Vegetables condition, a statistically significant difference emerged between the Real and the Unreal Target for the Identity Prime (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.09; p<.05), the Different Category Prime (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.16; p<.05) and the Baseline (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.73; p<.01), whereas the difference approximated significance in the case of the Same Category Prime (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.94; p=.05, trend). In the case of the Animals, the latencies were similar for the Real and the Unreal Targets for all the primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1; Identity: z=-0.48; p=.63, *n.s.*; Same Category: z=-0.45; p=.65, *n.s.*; Different Category: z=-1.46; p=.14, *n.s.*), with the exception of the Baseline (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.91; p<.01).

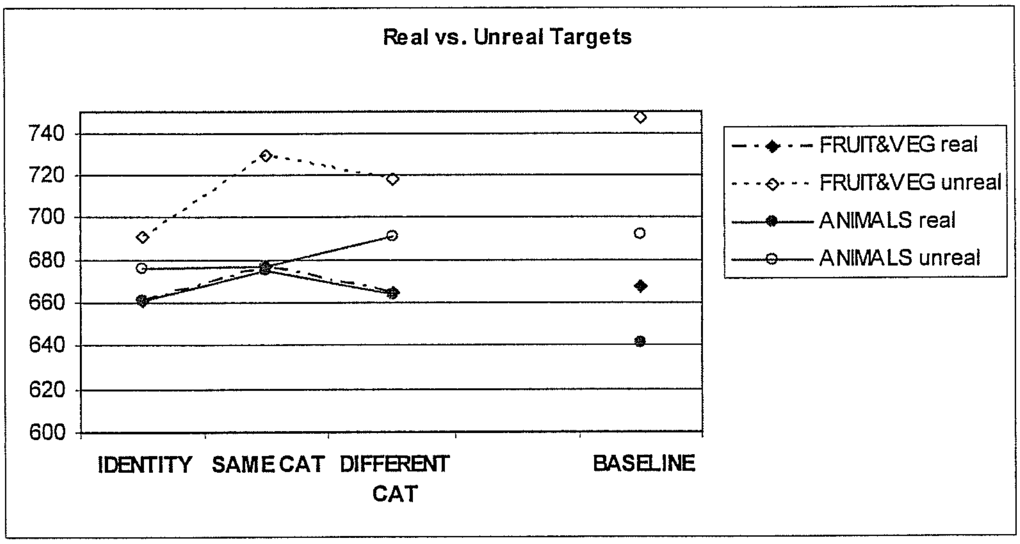

Figure 8. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

When the Fruits and Vegetables were contrasted with the Animals within each Prime condition, no differences emerged for none of the comparisons[22].

With respect to the accuracy (see Table 1), no differences emerged between the Real and the Unreal Targets in the case of the Animals (t-test: Real vs. Unreal Target, *df*=19, t=-0.82; p=.42, *n.s.*), while the subjects were less accurate for the Unreal Targets in the Fruit and Vegetables' condition (t-test: Real vs. Unreal Target, *df*=19, t=4.11; p<.001).

When the two categories were compared with respect to the target-type no differences emerged for the latencies (Wilcoxon Matched-Pairs Signed-Ranks Test: the Fruit&Veg vs. the Animals; Real Targets: *df*=1, z=-0.19; p=.85, *n.s.*; Unreal Targets: *df*=1, z=-1.64; p=.10, *n.s.*). With respect to the accuracy, no differences emerged between them for the Real Targets (t-test: Fruit&Veg vs. Animals, *df*=19, t=-0.36; p=.72, *n.s.*), while the Fruit and Vegetables were associated with lower accuracies than the Animals for the Unreal Targets (t-test: Fruit&Veg vs. Animals, *df*=19, t=6.34; p<.001).

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[22] Mann-Whitney U-test: Fruit&Veg vs. Animals, *df=1*; Real-Identity: z=-0.13, p=.89, *n.s.*; Real-Same Category Prime: z=-.30, p=.77, *n.s.*; Real-Different Category: z=-.16, p=.87, *n.s.*; Real Baseline: z=-.65, p=.52, *n.s.*; Unreal-Identity: z=-.54, p=-.59, *n.s.*; Unreal-Same Category: z=-.92, p=.36, *n.s.*; Unreal-Different Category: z=-.54, p=.61, *n.s.*; Unreal-Baseline: z=-1.22, p=.22, *n.s.*).

	Condition	
Target	**Fruit&Veg**	**Animals**
Real	0.94 (0.06)	0.94 (0.07)
Unreal	0.81 (0.12)	0.96 (0.04)

Table 1. Accuracy proportions (sd) of 20 subjects in the Object Decision, for the Real and the Unreal Targets of the two conditions.

3.3.4. Comment

The overall results of this experiment sustain the idea that the Fruit and Vegetables are treated in a different manner than the Animals: (1) an effect of prime emerged only in the case of the Fruits and Vegetables' condition, (2) the Fruit and Vegetables were associated with slower latencies and lower accuracy ratings than the Animals, in particular for the Unreal Targets. A possible explanation of the emergence of priming effects only for the Fruits and Vegetables is that this category requires more refined information than others –i.e. animals-, in order to distinguish between the exemplars (Warrington and McCarthy, 1987). Moreover, we claim that the task employed is more difficult than a standard object decision, since the pictures are not chimeras, but "real" objects manipulated with respect to their specific visual aspects, resulting in slower latencies in the case of the Unreal Targets and the categories which items are more difficult to distinguish (i.e. Fruits and Vegetables). In line with this, Price & Humphreys (1989) and Tyler et al. (2004) suggested an interaction between the kind of material (they spoke about *"structurally similar"* and *"structurally dissimilar"* categories) and the task requests (i.e. naming at category level vs. naming single exemplars of category). In our experiment, the Fruits and Vegetables would have been treated as a "structurally similar" category, while the Animals would have been treated as a more "structurally dissimilar" category. In detail, we found that the Fruits and Vegetables differed significantly in terms of the latencies when the Real and the Unreal Targets were compared (and this was true as a general effect of the condition and when comparing the latencies within each prime), whereas this was not true for the Animals. These results can be read as an "interaction" between the category and the kind of material (i.e. Fruit&Veg and Real-Unreal Targets, respectively) and they support the tentative interpretation given above.

3.4. Experiment 2: Object Categorization

3.4.1. Specific aim of the experiment and predictions

In the Experiment 2 we used an object classification task, to be performed according to a semantic intra-category criterion (i.e. to classify the animals as Exotic vs. European). We assume that such a task would require the Structural Descriptions plus the abstract-verbal knowledge in order to be solved (Figure 3), since the objects have to be identified (accessing the semantic information) in order to be classified according to an intra-category criterion. Thus, any effect of the prime found in this task can be interpreted as contribution of the visual surface aspects to both the structural descriptions and/or to the abstract-verbal representations.

3.4.2. Methods

Subjects

20 undergraduate students (F=13; mean age=24+/-2.6) were recruited for this experiment and paid for their collaboration. As in the previous experiments, all the subjects ran both conditions, in a fixed order. All the subjects had normal or corrected-to-normal vision.

Materials

Items The items were the same employed in the Experiment 1, and consisted in 13 Fruits/Vegetables and 14 Animals (see Appendix A).

Targets The target pictures corresponded to the Correct Targets of the previous experiment, while the manipulated shapes were not included (see paragraph 3.3.2).

Primes The same primes employed in the Object Decision Task (see paragraph 3.3.2) were used here, with the same logic adopted in the previous experiment.

Procedure

The subjects sit in front of the computer screen in a silent and well-illuminated room, with their index fingers on the response key buttons (keyboard "*c*" and "*m*" buttons). The number of the subjects that responded with the "*c*" or the "*m*" button to the Fruits and the European Animals, respectively, was counterbalanced in the two conditions (see later for classification criteria specification). Moreover, the handedness of participants was taken into account in assigning them to the two groups. The pictures appeared in the centre of the computer screen, through an E-prime Study.

Sequence of events A fixation (1cmX1cm black cross in the centre of a white background) appeared on the screen and lasted for 200 ms, followed by the Prime. The Prime disappeared after 25 ms, and was followed by a blank (175 ms) and the Target (time-limit for response=3000 ms). The ISI was 1200 ms and the SOA was 200 ms (see Figure 9).

Conditions and trials The subjects ran both the conditions (Fruits/Vegetables and Animals), with the same order (the Fruits/Vegetables first). As described above, the two conditions required the same task, with the only exception of the criterion of classification of the items. The Fruits and Vegetables condition implied 104 trials (13 items, presented twice for each Prime type), while the Animals condition consisted in 112 trials (corresponding to 14 items). A brief break was provided after 50% of the trials in each condition.

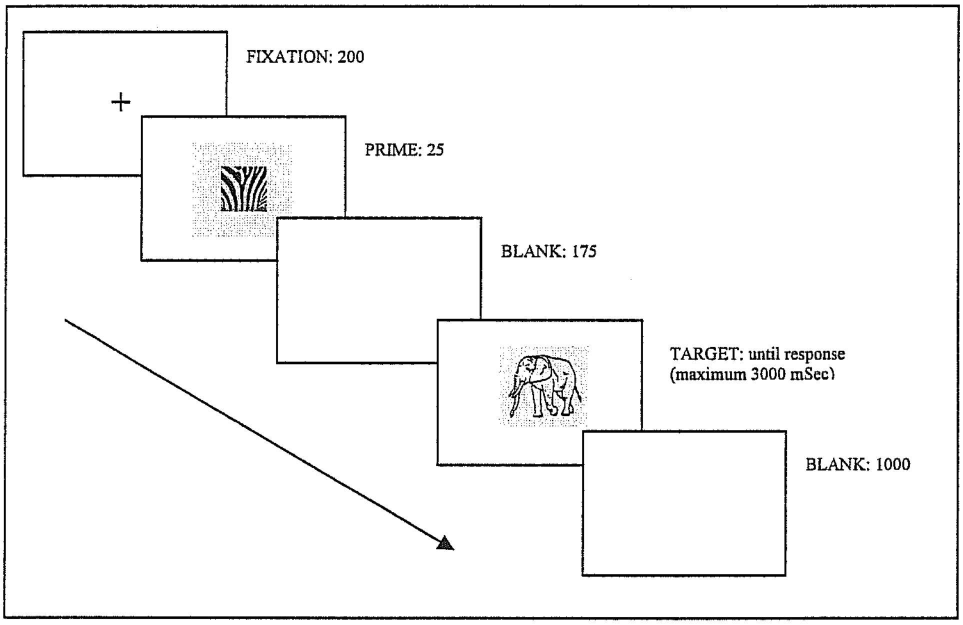

Figure 9. The Object Categorization sequence of events.

Task

The subjects were required to look at the line drawings appearing on the screen and to categorize the pictures according to a given criterion. In the first condition, they had to decide whether the pictures represented Fruits or Vegetables; in the second one, they had to differentiate between the European and the Exotic Animals[23].

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[23] Notice that in the first condition 5 out of 13 trials required a "Fruit"-answer, while 8 out of 13 trials required a "Vegetable"-answer; in the second condition the number of expected "European"-answers was 8, contra the 6 "Exotic"-responses.

The instructions asked the subjects to press as quickly as possible the key button corresponding to the correct-criterion; as in the Object Decision Task, written labels were given in order to prevent the mistakes and to faster the reaction times.

3.4.3. Results

The subjects' data were cleaned for the accuracy and the RTs means using the same procedure adopted in the Object Decision Experiment (see 3.3.3. for details and Appendix B, table b for data).

For the Fruit and Vegetables' condition (Figure 10), the analysis revealed a main effect of the Prime type (Friedman Test, *df*=3, χ^2=12.48; p<.01). The Identity Prime was contrasted with all the other primes considered together (Same Category + Different Category + Baseline), revealing a significant difference (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.46; p<.05); moreover, the Baseline was slower than the Same Category + the Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.39; p<.05).

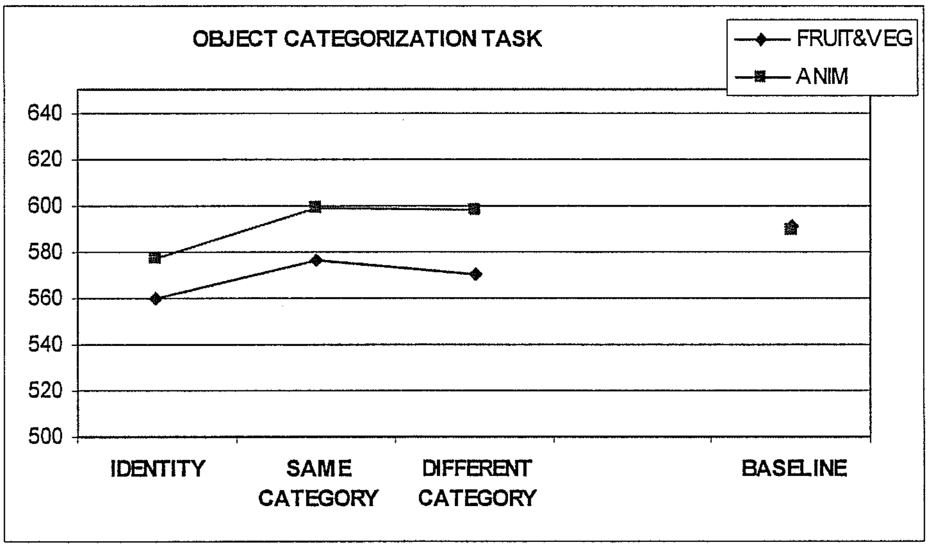

Figure 10. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

A strong trend towards significance emerged when comparing the Identity and the Same+Diff Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.87; p=.06). The Identity prime was faster than the Baseline (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.21; p<.005), while no differences emerged between the Same Category and the Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.90; p=.37, *n.s.*).

A main effect of Prime Type was found for the Animals (Friedman Test, *df=3*, χ^2=8.46; p<.05). The Identity was significantly faster than all the other primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.35; p<.05). The Baseline did not differ from Same+Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.48; p=.63, *n.s.*), and no differences emerged between the Same Category and the Different Category primes when directly contrasted (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.22; p=.82, *n.s.*).

When comparing the Fruit and Vegetables with the Animals no differences emerged between them in terms of latencies (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-.52 p=.60, *n.s.*).

3.4.4. Comment

In the Experiment 2 effects have been found for both sort of material, but for Fruits and Vegetables the main effect of the Identity was explainable as a Baseline effect. Crucially, and contrary to what found in the Experiment 1, the Fruits and Vegetables were no slower than the Animals: it seems likely that the animals need more time in order to be categorized, while it was the faster category in the Object Decision Experiment.

As previously suggested (see 3.3.4), the results found can be interpreted as "interaction" effects between the category characteristics (similarity between elements) and the kind of material (i.e. real or manipulated shapes). Here, the targets always correspond to the real objects and the task requires to classify the objects according to an abstract information (i.e. the geographical belonging). Thus, we suggest that in this case the salient characteristics of the two categories which can interact with the task requirements are different from those involved in the previous experiment: in detail, we suggest that in the Object Categorization the Animals would be treated as a "structurally similar" category as well as Fruits and Vegetables. We reasoned that a categorization task requires one to completely identify the objects presented, in order to allow the semantic information to be accessed (for example, you have to identify an Elephant before deciding it comes from Africa). However, if this interpretation is correct, we would expect a similar behaviour for both the categories, whereas the Fruits and Vegetables were found to behave differently from the Animals.

An alternative explanation can be derived from the analysis of the latencies. In fact, while in the Experiment 1 the slower latencies were associated with the Fruits and Vegetables (where effects were found), here the slower latencies were associated with the Animals, the category in which the significant effects emerged. Assuming that the latencies would be slowed down by the difficulty of the task, it seems plausible that deciding about the shape-reality is more difficult for the fruits and vegetables[24], while deciding about the sub-category membership is more difficult in the case of the animals. Thus, the difficulty of the task comes out in the slowing down of latencies; it is possible that effects arise only in the case of the slower conditions, since "giving time" allows the activation of the upper levels of representation to take place.

If this interpretation is correct, we can hypothesize that the surface features can contribute to the object representation only when the time is sufficiently long. In other words, the primes would activate the visual surface features of the objects, but time is needed since these representations spread their activation to the other kinds of representations of the corresponding object (i.e. shape, abstract information).

In any case, it appears reasonable to think that the surface features are with some respect interacting with the object's abstract representations.

3.5. Experiment 3: Word Categorization

3.5.1. Specific aim of the experiment and predictions

With respect to the tentative model presented in Figure 3, we would assume that the word-presentation activates the corresponding object's Abstract Verbal Knowledge (through the lexical instances); the activation would than spread to the Structural Description and, from there, to all the other representations. If there is a direct link between the Abstract Verbal Knowledge and the Surface Features, the effects found in the previous experiments would not be cancelled by the fact that shapes are not allowable.

The Experiment 3 aims to investigate the possible existence of a direct link between the Abstract Verbal Knowledge and the Surface Features representations,

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[24] For the Fruits and Vegetables, consider for instance a strawberry: in the case of the Object Decision, a strawberry with a completely rounded shape would be unreal, but still plausible; in the case of the Object Classification, there is quite universal agreement about its belonging to the fruits sub-class. For the Animals category, consider the tiger: it is quite easy to decide that a long-necked tiger is not a real one, whereas it can be more difficult to remember if the same animal belongs to Africa or India, for instance.

when the shape is not given. Thus, the question is the same addressed in the Experiments 1 and 2, with the difference that here the activation is supposed to involve the Structural Descriptions only as a "secondary" activation, not required for the task succeeding.

3.5.2. Methods

Subjects

The participants were 20 undergraduate students (F=9; mean age=24+/-3.7) recruited from a list of volunteers and paid for their collaboration in the experiment. They all had normal or corrected-to-normal vision. Both the conditions were presented in the same order to all the subjects (the Fruits and Vegetables first).

Materials

Items The items were the same employed in the Object Decision and the Object Categorization Experiments, consisting in 13 Fruits/Vegetables and 14 Animals (see Appendix A).

Targets The picture targets of the previous experiments were substituted with words, presented through an E-prime study in the exact centre of the screen (Figure 11).

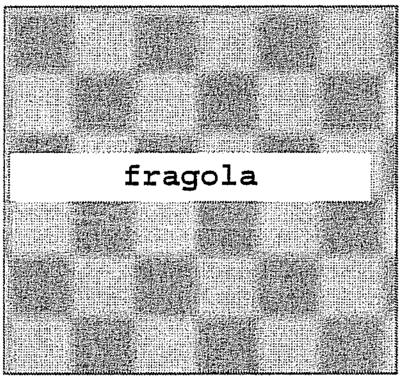

Figure 11. Example of word-target for Word Categorization Experiment.

The words were written in small fonts ["Courier New" font, black colour, size=24] and set in a white rectangular shape, in the centre of a blue colour chequered background[25].

Primes The same primes employed in the Object Decision Task (see paragraph 3.3.2) were used here, with the same logic adopted in the previous experiments.

Procedure

The procedure was identical to the previous experiments (see paragraph 3.3.2).

Sequence of events The sequence of events was the same described in the Object Categorization experiments, as represented in Figure 12.

Conditions and trials As in the other experiments, the first and the second condition implied 104 and 112 trials, respectively, and a break was presented after 50% of the trials.

Task

The participants were required to look at the screen and to silently read the word that would appear in the centre of it.

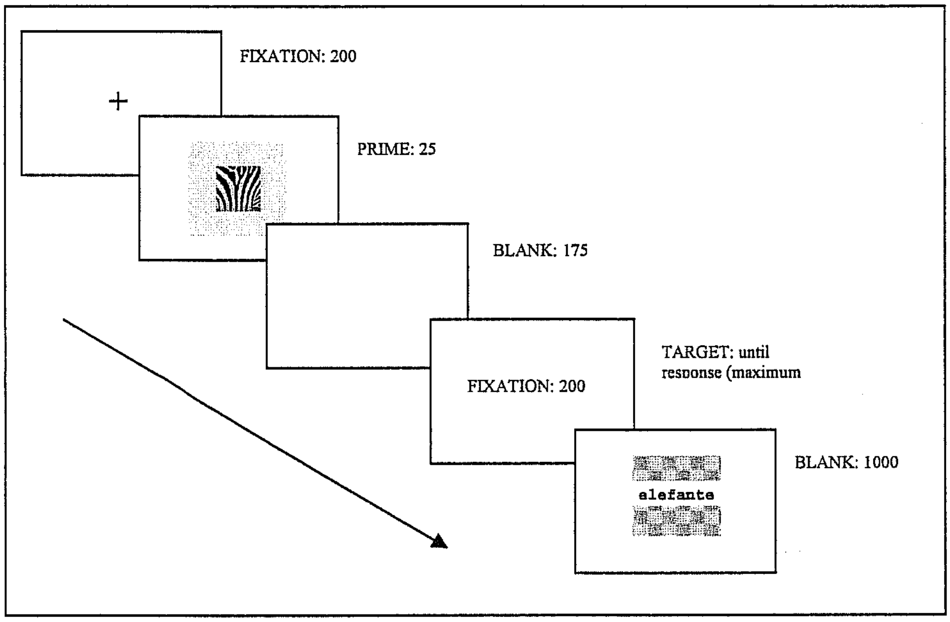

Figure 12. The Word Categorization sequence of events

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[25] The background was chosen in order to be different for colour and texture from all the primes involved in the experiment, but to maintain the size (145x145 pixels/0.61x0.61 cm) and the general visual characteristics quite invariant.

3.5.3. Results

The data were cleaned for the accuracy and the RTs (Appendix B, Table c), according to the procedure used in the previous experiments (see 3.3.3).

In the Fruit and Vegetables' condition (Figure 13), the statistical analysis failed to reveal a main effect of the Prime (Friedman Test, *df=3*, $\chi^2=4.38$; p=.22, *n.s.*).

A main effect of the Prime was found in the Animals' condition (Friedman Test, *df=3*, $\chi^2=10.86$; p=<.05). The Identity Prime was significantly faster than the other primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.06; p<.01) and the Baseline was faster than the Same Category + Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.09; p<.01). Moreover, the Identity was faster than the Same + Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.27; p<.005), while no differences emerged between the Identity and the Baseline (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.01; p=.31, *n.s.*) nor between the Same Category and the Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.64; p=.10, *n.s.*).

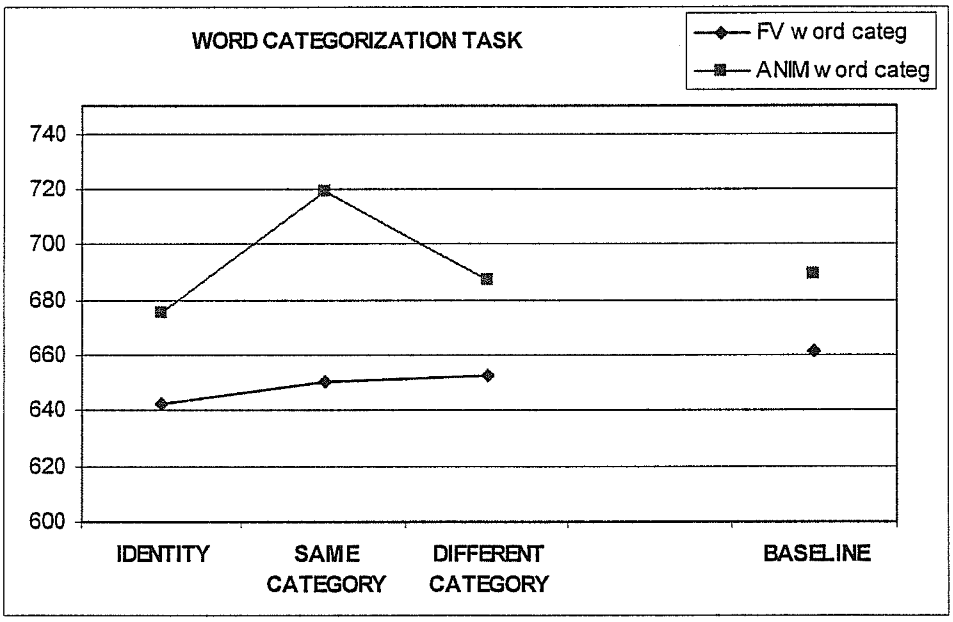

Figure 13. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

When comparing the two categories directly, the latencies were slower for the Animals condition than for the Fruits and Vegetables one (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.9; p<.05); moreover, the accuracy was significantly lower for the Animals than for the Fruit and Vegetables (T-test: Fruit&Veg vs. Animals, *df*=19, t=-2.51; p<.05[26]).

3.5.4. Comment

As observed in the Object Decision and the Object Categorization, priming effects emerged for one category only (i.e. the Animals), suggesting that an interaction between the task and the kind of material is occurring, in line with what proposed by Price & Humphreys (1989) and Tyler et al. (2004).

In light of the proposed model (Figure 3), the presentation of a target-word would activate the Lexical Representations firstly and then the conceptual representations associated with the word itself (Semantic Memory). According to the second kind of model proposed (see Figure 3-B), the activation of the Verbal Semantics through the Lexical Representations would be necessary for the secondary activation of the Visual Semantics. In our priming experiment, the surface features presented as primes would have determined a previous activation of some visual representations of the object. In our tentative model, we hypothesized that activation could spread from the Surface Features (activated through the visual input) to the shape-representations (Structural Description) and directly to the semantic components: a unitary Semantic Memory or to Visual Semantics (Figure 3 -A- and -B-, respectively). Irrespectively from the nature of the semantic system adopted, we suggested that the conceptual knowledge linked to an object can be activated starting from a surface feature.

Obviously, one can object that the Surface Features can also activate the Semantics indirectly, through the Structural Description activation, and this position is supported by the fact that the latencies were slower for the Word Categorization than for the Object Categorization Experiment[27], as usually found in the literature.

However, the latencies associated with the Object Categorization experiment were faster than the latencies in all the other experiments, suggesting the existence of a specific facilitation in this kind of task, more than the slowing down of latencies in the others.

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[26] The accuracy proportions (sd) were 0.97 (0.03) in the Fruit and Vegetables' condition and 0.95 (0.04) in the Animals' condition.

[27] Mann-Whitney Test, Object Categorization vs. Word Categorization (*df=1*): Fruits and Vegetables: z=-2.41, p<.05; Animals: z=-2.72, p<.01).

In terms of the proposed model (see Figure 3), we can imagine that the activation spreads from the Surface features to the corresponding Structural Descriptions, and only through these shape-representations the activation of the Semantics is achieved. On the other hand, the lexical instances are activated by the target presentation and the summation of this double activation of the Semantics would generate facilitation in the case of the Identity prime presentation.

However, the effects found in the Word Categorization can be interpreted as "interference" effects generated by the presentation of primes not matching the target-word, since the RTs were slowed down by the presentation of the Same and the Different Category primes, while the latencies were faster for the Identity prime and the Baseline, which do not differ one each other (see the previous section).

One possible explanation of these interference effect is that they are generated by the activation of the Semantic Memory by the Surface Features via the Structural Description representations (Figure 3). If this is the case we have also to suppose that the activation spreads from the Structural Description of one object (activated, for instance, by the presentation of the Same Category prime) to all the similar ones (including the target-object, which corresponds to the Target word).

Alternatively (and more likely, in our opinion), the Surface Features activate directly the abstract representations corresponding to their object of belonging within the Semantic Memory. The activation of the abstract representations in the Semantic Memory would in turn generate a spreading of activation to the neighbour-representations, including the one corresponding to the Target word. The Lexical Representation would have been previously activated by the presentation of the Target word, so that the summation in activation coming from the Surface Features and from the lexical instances would generate a facilitation or an interference effect.

The problem of the activation of the Semantic Memory via the Structural Descriptions will be taken in account further in the Discussion of the Chapter (see 3.8).

3.6. Experiment 4: Picture-Word Compounds Categorization

3.6.1. Picture-Word paradigms

In the standard Picture-Word paradigms a target picture is presented together with a superimposed word, with the aim to simultaneously activate the lexical representation corresponding to the picture (through the concept-mediation) and the semantic representations (directly). In this light, the interference effects in the picture naming can be thought as the result of the competition between the different activated alternatives at the lexical level (Glaser & Glaser, 1989): in detail, the picture activates its corresponding concept and lexical representations; moreover, an additional activation spreads from the picture to the semantic neighbours and the corresponding lexical representations, resulting in a high degree of competition. In terms of the model proposed in Figure 3, we can assume that the presentation of a picture activates the Structural Description and the associated representations, while the presentation of a word would activate the Lexical Representations and, from there, the activation would spread to the other representations. The competition would occur when the lexical instances are very close in the representational space within the Lexical store.

Glaser & Glaser's study has been recently criticised by La Heij, Heikoop, Akerboom and Bloem (2003), which showed that the word-picture paradigms can determine a facilitation more than an interference effect. They argued that the picture presentation does not necessarily determine the activation of the corresponding lexical representations; on the contrary, the pictures are supposed to activate an abstract representation (the Abstract Verbal Knowledge, in the proposed model), that can interfere with the other (related) concepts (including those activated by the word).

In any case, for both the positions (Glaser & Glaser 1989 vs. La Heij et al. 2003) the spreading of activation is supposed to occur from the picture-concept to its semantically related neighbours[28]. Interestingly, La Heij et al. 2003 claim that in the standard paradigm (naming of pictures) facilitation effects can be found, while interference effects can be observed when the subjects are required to categorize the words.

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[28] The difference is that Glaser & Glaser (1989) position assumes a spreading of activation taking place at the lexical level, while La Heij et al. (2003) claim it occurs at the concept-level.

3.6.2. Specific aim of the experiment and predictions

The word-picture paradigm can be seen as a special case of "priming", in which the SOA is equal to "0": the word of word-picture paradigms is the same as the target of our priming experiments, whereas the picture can be seen as the prime. Since in this paradigm the "prime" and the "target" are simultaneously presented, the SOA corresponds to zero. If we consider the word-picture paradigms as a special case of priming, we can use it to replicate the Experiment 3 with a SOA=0. This would be helpful, in order to exclude activation timing differences across the categories and in order to elicit interference effects, which are typically observed in the word-picture paradigm experiments. Interestingly, Damian & Bowers (2003) found interference effects due to semantically related words on the target-pictures only for SOA=0 (and not for negative or positive ones). In line with this, we use a SOA=0 in our Word-Picture Compound Categorization experiment[29].

Any facilitation/interference effect determined by the primes would be interpreted as an additional proof of the possibility of the surface details to activate the related-concept, without the shape-mediation. In detail, we would expect that the Identity Prime would reinforce the target-word activation, resulting in a facilitation effect on the latencies, while - following La Heij et al. (2003)- we would expect the Same Category prime and the Different Category prime to create competition and, thus, the interference (slowing down the latencies).

3.6.3. Methods

Subjects 20 students (F= 12; mean age=26+/-3.9) recruited from a list of volunteers were paid for their participation in the experiment; all had normal or corrected-to-normal vision.

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[29] It is worth noting that their task is comparable to ours only in the case of simultaneously presentation of the picture and the word (SOA=0). In the other conditions a sequential activation of the lexical and the visual representations is supposed to take place, similarly at least for the positive SOA, to the priming experiments (negative SOA>lexical→visual; positive SOA>visual→lexical). In Experiment 3 (3.5) we used a positive SOA (200 ms), and we found an effect of facilitation; on the contrary, they failed to find effects for the positive SOAs (and negative ones as well). In any case, Damian & Bowers (2003) used a naming task, while we use here a categorization task, which maybe relies on quite different processes (see the Comment, 3.6.5).

Materials

Items The items were the same employed in the all the previous experiments and consisted in 13 Fruits/Vegetables and 14 Animals (see Appendix A).

Targets The targets corresponded to the Primes of the previous experiments (Paragraph 3.3.2) on which the words corresponding to the target-words of the Experiment 3 were superimposed. The words were written in black font (Courier New, size=24) in a white rectangular, superimposed on the prime-background. The word-frame appeared half times superimposed to the right side of the prime-background and half times over the left side of the same picture (see Figure 14); in both cases, the white rectangular was anchored to the centre of the prime-background, so that the same area of the background was covered in all the presentations.

Procedure

The subjects sit in a silent and lit room, in front of the computer screen. They were asked to put their index-fingers on "*c*" and "*m*" buttons of the keyboard and to look at the words that will appear on the screen.

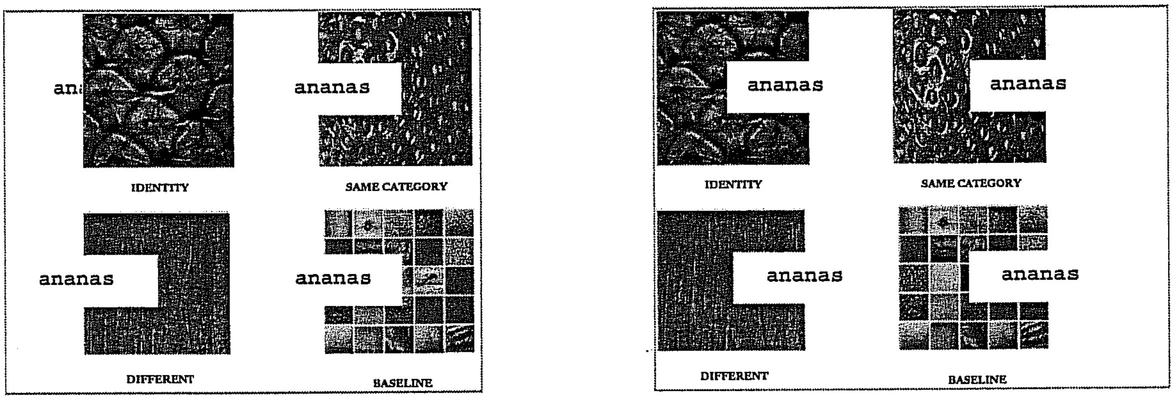

Figure 14. Examples of targets for the Word-Picture Compounds Experiment. The two pictures show the 4 possible targets for *pineapple* ("ananas") with words presented on the left or the right, respectively.

Sequence of events A fixation (the same used in the previous experiments, see 3.3.2) appeared on the screen and lasted 1000 ms; after that the Target appeared and lasted until response was given, with a time-limit of 3000 ms (Figure 15). The Inter Trials Interval was 1500 ms (blank).

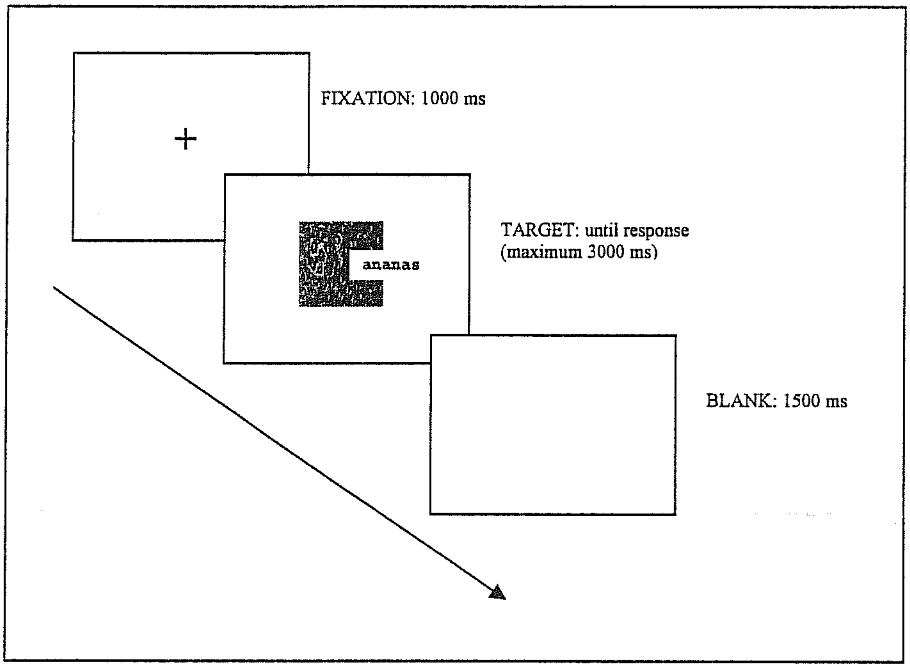

Figure 15. The Picture-Word Compounds Experiment sequence of events.

Conditions and trials As in the previous experiments, the subjects ran both the conditions (the Fruits/Vegetables first), consisting in 104 and 112 trials, respectively. A break was allowed after 50% of the trials in each condition.

Task

The participants were required to look at the words that would appear in the centre of the screen; they were told not to pay attention to the word backgrounds and, crucially, the instructions did not tell anything about the nature of these background-pictures. As done in the previous experiments, the subjects were asked to categorize the words as quickly as possible, pressing one of two key-buttons, according to the given criterion (written labels were provided in proximity of key-buttons, showing the two alternative answers). The proportions of "*fruit*" vs. "*vegetable*" and "*European*" vs. "*exotic*" responses, in the first and second condition, respectively, were the same of the Object categorization experiments (see paragraph 3.4.2 for details).

3.6.4. Results

The data was cleaned following the same criteria employed in the previous experiments, so that the wrong response-trials were not considered, and the latencies +/-2 standard deviations from the total average were not included in the statistical analysis (see Appendix B, Table d). A main effect of the Prime was found (Friedman Test, *df=3*, χ^2=15.12; p<.01) in the Fruit and Vegetables' condition (Figure 16). The Identity Prime was faster than all the other primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.02; p<.005), and the Baseline was faster than the Same Category and the Different Category primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-2.98; p<.005). The Identity Prime was not different from the Baseline (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.31; p=.19, *n.s.*), while it was faster than Same+Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.25; p<.005). No differences emerged when comparing the Same Category and the Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.04; p=.30, *n.s.*).

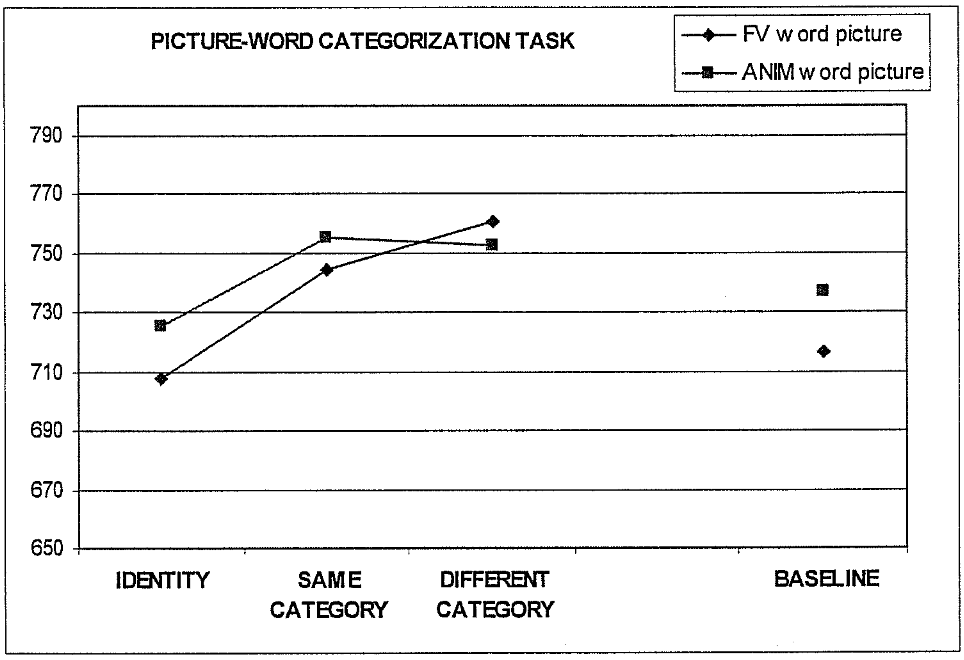

Figure 16. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

The statistical analysis on latencies for the Animals' condition (Figure 16) revealed an effect of Prime that failed to reach significance (Friedman Test, *df=3*, χ^2=6.3; p=.098). However, the Identity was faster than all the other primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-3.21; p<.005), while no differences emerged between the Baseline and the Same Category + Different Category Primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.19; p=.85, *n.s.*). Moreover, the latencies associated with the Same Category and the Different Category primes did not differ (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.30, p=0.76, *n.s.*).

No differences emerged between the overall latencies of the two categories (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.26; p=0.79, *n.s.*).

3.6.5. Comment

As predicted, the Picture-Word Compounds Categorization Experiment showed effects of facilitation of the Identity Prime over the Same Category and the Different Category primes in both the conditions, even if the main effect of the prime was not significant in the case of the Animals. Moreover, in the case of the Fruits and Vegetables, the Same Category and the Different Category Primes were slower than the Baseline latencies, evidencing an interference effect due to the presentation of the surface aspects not matching to the target word. The interference effects have been interpreted as the result of competition between the different, but semantically related, representations (Glaser & Glaser, 1989). If this is true, the findings in Picture-Word Compounds Categorization can be interpreted as a proof of a direct interaction between the surface features and the Abstract Verbal Knowledge (independently from shape mediation). Glaser & Glaser (1989) suggested that two different processes can be at the basis of the competition effects: when the instructed task requires responding to the visual target, the conceptual representations will be activated and - after that- the corresponding lexical representations will be activated (Figure 17); on the contrary, when the instructed task requires responding to the target word (as in the current one), the pre-semantic/lexical representations will be activated first, and only after that the conceptual representations will be activated (Figure 17).

Target **Picture** → activation of conceptual representations → and then → activation of lexical representation

Target **Word** → activation of lexical representations → and then → activation of conceptual representation

Figure 17. Two streams of activation supposed to occur (reformulated from Glaser & Glaser, 1989) when pictures or words, respectively, are presented.

In this kind of paradigm, the two targets cannot compete before they both have reached the conceptual/semantic access. On the contrary, in the priming studies the time given during the SOA-window allows the complete processing of the visual prime until reaching the activation of the lexical representation components. However, the word-picture interference paradigm requires a very fast processing of the target, since the response is given concurrently to the prime-presence; thus, it seems reasonable to think that the interference effects are based on the conceptual competition more than on a lexical mediation[30]. This interpretation reinforces the idea that the visual features used as primes in our experiments can actually interact with the semantic representations.

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[30] Someone could object that the categorization can occur at the lexical level, at least for the well-known categories (such as vegetables); however, we think it is implausible that this is the case for the Animals' condition, in which, as suggested before, a more arbitrary categorization is required.

3.7. Experiment 5: Picture-Word Compounds categorization -pure texture and pure colour experiments-

3.7.1. Specific aim of the experiments and predictions

These two experiments aim to investigate whether the surface aspects can interact with the object semantic representations even if they are presented as separate dimensions, i.e. colour vs. texture. For this reason, the Picture-Word Compounds Categorization was replicated employing the textures without the colour dimension and, in a further experiment, using the colour without the texture information. If the surface aspects are represented according to the different (and separate) dimensions, an effect of the prime should be found in both the experiments. On the contrary, if these aspects are stored and represented as bounded information, slighter or no effects should be found in these two "separate" conditions.

3.7.2. Methods

Subjects The participants were recruited from a list of volunteers and paid for their participation: 20 subjects (F=12; mean age=26+/-3) collaborated to the Texture Experiment and 20 subjects (F=9; mean age=23+/-3) were employed in the Colour Experiment, respectively. All had normal or corrected-to-normal vision.

Materials

Items The items were the same employed in all the previous experiments (see Appendix A).

Targets The targets corresponded to those used in the previous experiment, but they were varied with respect to the background "prime". In detail, in the Texture Experiment the colour was eliminated from the pictures, whereas in the Colour Experiment the texture details were not included, so that the backgrounds were "pure colour" patches (see Figure 18).

Procedure In both the experiments the procedure was identical to the previous experiment (see 3.6.3).

Sequence of events A fixation (see 3.3.2) lasted 1000 ms; the Target appeared immediately after and lasted until the response (time-limit=3000 ms). The Inter Trials

Interval was 1500 ms (blank). The sequence of events was identical in the two experiments.

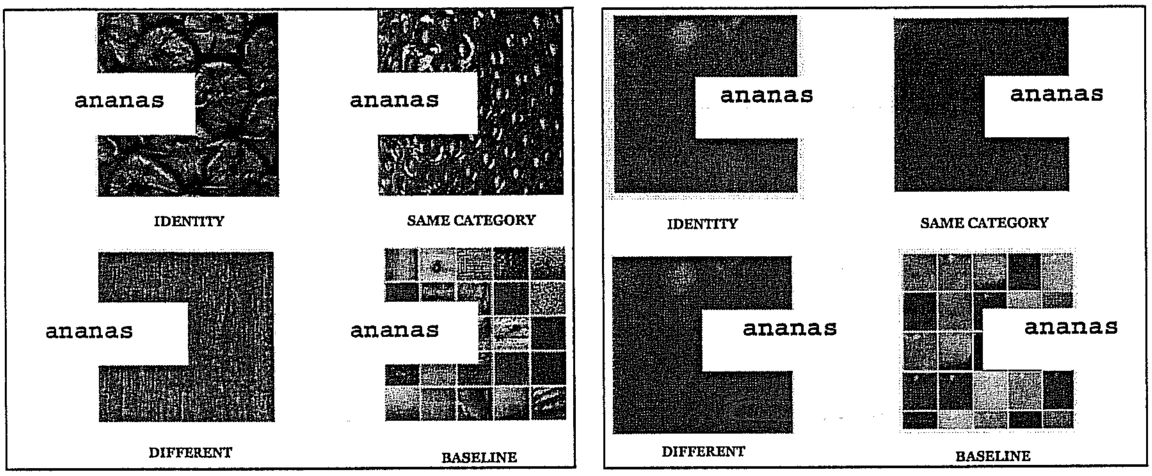

Figure 18. Examples of targets (*pineapple*) for the Word-Picture Compounds Experiments. From left to right: the Texture and the Colour Experiment, respectively.

Conditions and trials As in the previous experiments, the subjects of each experiment ran both the conditions (the Fruits/Vegetables condition before), which consisted in 104 and 112 trials, respectively. A pause was allowed after 50% of the trials in each condition.

Task

The subjects received the same instructions described for the previous experiment (see 3.6.3).

3.7.3. Results of the Texture Experiment

The data was cleaned excluding from the statistical analysis the wrong response-trials and the latencies +/-2 standard deviations from the total average (see Figure 19 and Appendix B, Table d).

The analysis did not reveal a main effect of the Prime in the Fruit and Vegetables' condition (Friedman Test, *df=3*, χ^2=1.08; p=.78, *n.s.*) nor in the Animals' condition (Friedman Test, *df=3*, χ^2=4.08; p=.25, *n.s.*).

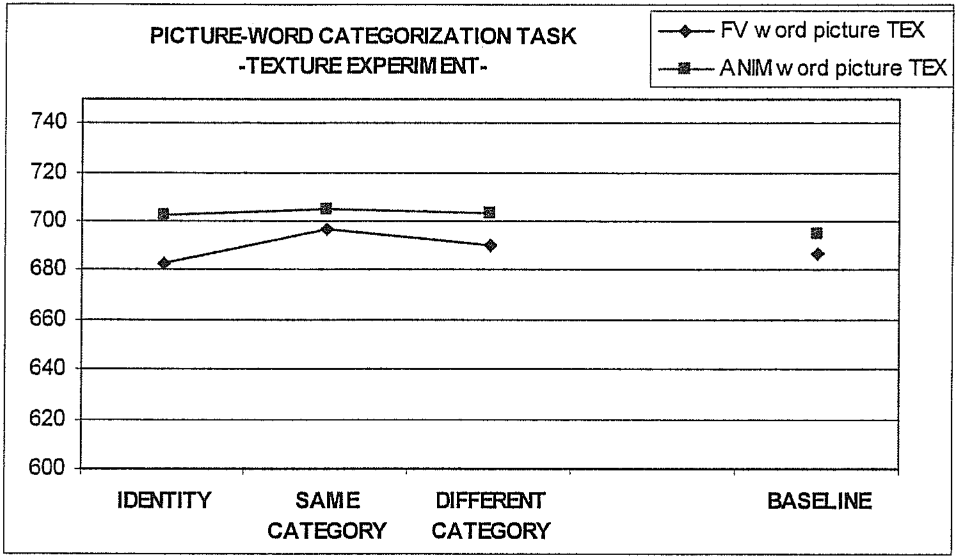

Figure 19. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

3.7.4. Results of the Colour Experiment

The same cleaning procedure was adopted as in the previous experiments (the results are graphically represented in Figure 20). The analysis revealed no main effects of the Prime in the Fruit and Vegetables condition (Friedman Test, *df=3*, χ^2=4.56; p=.21, *n.s.*), while a trend towards significance was found in the case of the Animals (Friedman Test, *df=3*, χ^2=7.38; p=.06, *n.s.*).

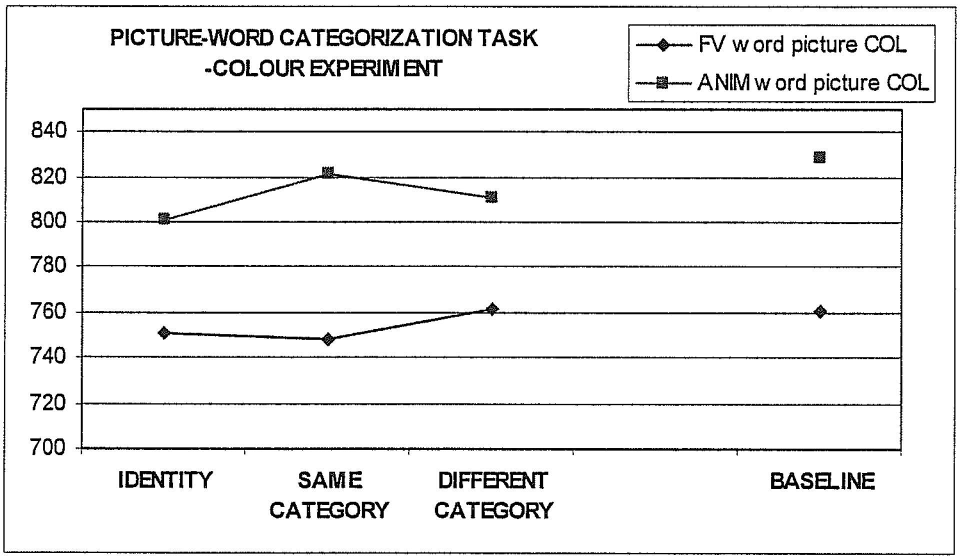

Figure 20. The RTs of the 20 subjects (average in mSec) for the two conditions and the 4 different primes.

Within the Animals' condition, the Identity Prime was faster than all the other primes considered together (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.94; p=.05). The Baseline was not different from the Same + Different Category primes (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-1.04; p=.29, *n.s.*), and no differences emerged when the Same Category and the Different Category primes were directly compared (Wilcoxon Matched-Pairs Signed-Ranks Test: *df*=1, z=-0.07; p=.94, *n.s.*).

3.7.5. Comment

We failed to find effects of the prime in the Texture Experiment, while some effects, even if slight, are found in the Colour Experiment (the Animals' Condition). These findings suggest that the colour and the texture can contribute in the object representation as a bounded representation (even if they can be possibly processed as separate dimensions –i.e. there is a slight effect of the Identity Prime for the Animals, in the Colour experiment!). Similarly, Price and Humphreys (1989) failed to find facilitation in terms of the naming latencies when the texture information was added in the coloured pictures (i.e. the coloured photographs were named as fast as the coloured line-drawings); however, contrary to our results, they found a facilitation in the case of the black-and-white pictures (texture information without colour) over the line-drawings, concluding that the texture information can be separately activated. However, it is worth noting that, differently from Price and Humphreys (1989), we did not use a naming task in these experiments: maybe naming and word categorization result in different paths of activation and in gross differences in the latencies, thus allowing different levels of representation to be involved.

3.8. Discussion

3.8.1. Summary of the results and comments

In this chapter we presented the results of 6 different experiments, which involved two categories of objects as targets (i.e. Fruit and Vegetables, Animals), while the visual details of the same objects were used as primes in different kinds of paradigms.

We focused on the role of the visual surface of objects, in order to investigate different issues that are still under debate. In detail, we aimed to understand whether the surface aspects can be represented as part of the object concept and whether they can be activated separately from the Structural Descriptions; more specifically we were interested in seeing at which level of representation the visual features interact with the object representation (Structural Description vs. Semantic Memory). Table 2 reports a general summary of the results.

(1) As a first result, we found that the Fruits and Vegetables behaved differently from the Animals' category.

The differential behaviour of the two categories in the Object Decision was initially interpreted in line with Price & Humphreys (1989), who suggested that the structurally-similar categories behave differently from the structurally-dissimilar ones, since the former classes require more resources in order to distinguish between their exemplars. In the Experiment 1 (3.3.4), we suggested that the Fruits and Vegetables could be considered as a structurally similar category, whereas the Animals as a structurally dissimilar one. Moreover, Ostergaard & Davidoff (1985) claimed that the recognition and the naming tasks require the activation of different representations (i.e. pre-semantic and semantic ones, respectively).

Thus, it seems more plausible to conclude that it is not the kind of processing required by the task that contributes in creating differential effects for the two categories, but the time needed in order to perform the task. In other words, when the time required to analyse the targets is longer, the probability that the activation spreads to the upper-level-representations (abstract knowledge) is higher, and this can determine the priming effects. This kind of interpretation would explain why, in the different tasks, the presentation of a visual prime would determine differential effects in the two categories and for different kinds of targets (i.e. *pictures* vs. *words*). If this interpretation is true, we can conclude that the surface features used as the primes activated the upper levels of representation only when sufficient time was given.

From this, we suggest that the surface features used as the primes correspond to the visual object's information that can contribute to the conceptual abstract representation of the objects. Moreover, we sustain that this contribution can occur quite independently from the Structural Descriptions, since the effects were found also in the case of the word classification tasks.

EXPERIMENT	**FV**	**ANIM**
OBJ DEC TOT	ID<B+SC+DC B=SC+DC	no main effect of prime
OBJ DEC REAL	no main effect of prime	ID > B+SC+DC B<SC+DC ID=B
OBJ DEC UNREAL	no main effect of prime	no main effect of prime
OBJ CAT	ID<B+SC+DC B>SC+DC ID=SC+DC and ID<B SC=DC	ID>B+SC+DC B=SC+DC SC=DC
WORD CAT	no main effect of prime	ID<B+SC+DC B<SC+DC ID<SC+DC and ID=B SC=DC
WORD-PICT INTERF	ID<B+SC+DC B<SC+DC ID<SC+DC and ID=B SC=DC	no main effect of prime
WORD-PICT INTERF TEX	no main effect of prime	no main effect of prime
WORD-PICT INTERF COL	no main effect of prime	no main effect of prime

Table 2. Summary of Priming and Interference Experiments results.

Legend: OBJ DEC= object decision (Experiment 1); OBJ CAT=object categorization (Experiment 2); WORD CAT= word categorization (Experiment 3); WORD-PICT INTERF= Word-Picture Compound Categorization (Experiments 4-5-6); REAL= Real Target and UNREAL= Unreal Target (in Experiment 1); TEX= texture and COL=colour (in Experiments 5 and 6, respectively). ID= Identity prime; SC= Same Category Prime; DC= Different Category Prime; B=Baseline. The symbols ">" and "<" refer to the statistically significant differences (> implies the first condition slower than the second one, < implies the first condition faster than the second one; = implies no differences). "No main effect of prime" refers to the statistical analysis performed on the 4 primes considered as a unique variable ("prime").

Furthermore, we suggested that the Semantic Representations are not activated via the Structural Descriptions in the case of the Word Categorization Experiment, where the results were interpreted as interference effects (see paragraph 3.5.4). This conclusion is not in line with Walker & Hinkley (2003), who suggested that colour needs the Structural Description mediation in order to activate the object representation[31], and Price & Humphreys (1989), who presented an experiment in which colour did not have an effect on the shapes, if it did not fall on the object surface. Moreover, our results did not fit with Biederman & Ju (1988), who claimed that the shape recognition does not require the surface information in order to be succeeded.

(2) In general, the results showed that when the surface details (colour + texture) are presented as the prime, and they match the target (<u>Identity prime</u>), a facilitation in terms of latencies can occur.

This was true for the Fruits and Vegetables in the Object Decision Experiment (see 3.3.3) and in the Object Categorization (see. 3.4.3), for the Animals in the Object Categorization Experiment (3.4.3) and in the Word Categorization task (3.5.3).

In the Picture-Word Categorization Experiment both the categories showed a general advantage in terms of latencies for the Identity prime presentation, even if the main effect of prime was not significant in the case of the Animals condition (3.6.4).

In general, a specific activation of the target representation seems to occur when the Identity prime is presented, whereas such activation seems not to be present when the details of other (semantically related) objects are presented. The specificity of the priming effect supports the hypothesis that the surface visual features are actually interacting with some level of the object representation; however, the general activation of the category is unlikely to support the fine object processing needed to succeed this kind of task.

However, a problem arose when considering the primes different from the Identity: in fact, it appears clear that the **Same Category and the Different Category primes were treated as similar material** (no differences emerged between these primes in any condition). As previously suggested, this can be possibly

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[31] Notice that Walker & Hinkley (2003) used letters as stimuli, so that the comparison between their task and our is not completely pertinent (see 2.2.6 for more details).

due to the way in which these primes were built up (see 3.3.2). Since the Same Category and the Different Category primes were similar, they would have been treated, alternatively (a) as "skins" belonging to the same category of the target, (b) as something totally different from the following target -that is, as belonging to the opposite sub-category than the target-. The problem is not trivial, since the existence of priming effects due to the Same Category primes would have been interpreted as the evidence that the surface features used as the primes were semantically represented (allowing the effects on semantically related but not corresponding targets). Crucially, even if the effects of these primes were not sufficiently strong in the Experiments 1-3, the Picture-Word Compounds Categorization experiment (3.6) showed an effect of interference due to the Same Category and the Different Category primes (evident in both conditions, but reaching significance only for Fruit and Vegetables -see 3.6.4). This result confirms the idea that the cognitive system interpreted these primes as features belonging to the target-objects, so that the interference effects were likely to be determined by the competition between the several neighbour representations simultaneously activated (see the next point).

(3) The interference effects found in the Picture-Word Compound Categorization experiments (3.6.4) are in line with the literature about the Picture-Word Interference paradigms (Glaser & Glaser, 1989), and reinforce the idea that something specific is happening with the Identity prime (see 3.6.5).

(4) The priming effects disappeared in the last two experiments (the Word-Picture Compound Categorization tasks, where the primes were pure colour or pure texture; see 3.7.3 and 3.7.4), showing that the **surface features can contribute to the object representation only when the different aspects (i.e. colour and texture) are presented bound together (3.7.5).**

3.8.2. Fulfilling the aims

In the paragraph 3.2.2 we proposed two alternative models for the access to the stored information about the visually presented objects (see Figure 3). They both start with the early visual processing, which is supposed to activate, possibly in a parallel fashion, both the shape aspects and the surface features. In turn, the shape analysis would activate the corresponding stored information about the gross shape, the parts, the details and the global representation of the object structural description. We hypothesized that the visual analysis of the surface features would activate, in the same fashion, the corresponding memory traces about these characteristics, assuming that they are represented in memory. The two models differ with respect to the semantic memory store, which is assumed to be unique in the first model (see Figure 3 –A) and fractionated in a verbal and a visual component in the second one (Figure 3 –B), according to the literature debates about the semantic memory structure (see the Chapter 4 for details).

In any case, we would like to test the hypothesis that the Surface Features can activate the Semantic memory, accessing the representations which describe the visual surface characteristics of the objects. In detail, we had three specific aims.

The first was to explore the ***contribution of the surface features*** in the activation of the object representations. The finding of a general effect of priming in our experiments and, in particular, the existence of an Identity Prime effect in some of the conditions - -see 3.8.1, point (2) – sustains the hypothesis that the surface features do contribute to the object representation. Crucially, the effects were variably found for the different tasks and, more importantly, for the different kinds of the target. The emergence of an Identity prime facilitation restricted to the visual target-conditions (i.e. the Object Decision and the Object Categorization experiments) would not have excluded the possibility that the effect was based on the Structural Description activation only, and not on the activation of the semantic representations.

However, we found the Identity Prime effects in the conditions involving the verbal-targets as well (i.e. the Word Categorization and the Word-Picture Compounds Categorization experiments). These findings sustain the idea that the Surface Features representations are actually activated by the visual surface aspects, and that in turn they can activate (directly or indirectly) further object semantic information. It is worth noting that the categorization tasks employed in the study were based on semantic dimensions not directly derivable from the target visual cues (e.g. the geographical belonging, in the case of the animals). We suggested that this activation is direct, and that it spreads from the Surface Features representations to the Semantics, without the needing of the Structural Descriptions activation. This was supported, in our opinion, by the emergence of the interference effects in the Word Categorization experiment (see 3.5.3) and, in particular, in the Picture-Word Compounds Categorization experiment (see 3.6.4). Such interference effects are based, in our opinion, on the activation of the semantic related instances, more than on the activation of the similar representations at the Structural Description level[32] (but see later, the next point, for other comments).

In the Chapter 2 (but see also paragraph 3.1.1 of this Chapter) we presented some studies in which the role of the visual features in the object recognition and representation has been taken into account. In particular, Davidoff & Ostergaard (1985) and Price & Humphreys (1989) added evidence in favour of a positive influence of the surface features in the object recognition and classification, sustaining -in line with our results- the idea of a strong role of such information in the object representation.

In terms of the proposed model (Figure 3) we can suggest that –when the shape is presented as the target (as in the Object Decision and Object Categorization experiments, see 3.3 and 3.4, respectively)- the activation spreads from the Structural Description to the Surface Features. This kind of spreading, resulting in complex representations, fits with recent models of recognition memory, introduced in the previous Chapter (i.e. Bussey and Saksida, 2002; Tyler et al., 2004). These models suggest that the visual representations are organized hierarchically, according to a posterior-anterior axis along the occipito-temporal areas; in such views, the single visual features can be represented independently one each other, but they are combined in complex representations, which are supposed to be localized in the anterior areas of the infero-temporal cortex. Crucially, we found that the two categories of objects used in our study (i.e. the Fruits/ Vegetables and the Animals) behaved differently in the diverse conditions, and we explained this in terms of the task difficulty, that is *time* required in order to succeed in the task. As previously commented (3.4.4 and 3.8.1 –point 1-), it is possible to think that the surface features used as the primes can activate their corresponding representations in memory and then activate further levels of representation, but only when sufficient time is given, allowing the necessary spreading of activation. In our opinion, this kind of interpretation is in line with the hierarchical binding models, proposed by Bussey and Saksida (2002) and Tyler et al. (2004).

The second aim of the study was to see whether ***the surface features can be activated independently from the shape dimension***. As previously discussed (see 3.8.1 -1-), the emergence of the priming effects in the verbal-target conditions

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[32] Consider that the Surface Features-primes were selected irrespectively from the shape similarity between the objects of belonging.

sustains the hypothesis that the surface features (used as the primes) can activate the semantic information about the objects (needed in order to solve the task) bypassing the structural description activation.

Moreover, this conclusion is reinforced by the emergence of the interference effects due to the Same Category and the Different Category primes (in the Picture-Word Compound Experiments: 3.6.4). The characteristics not corresponding to the target, in fact, can interfere with the target analysis only if they are recognized as part of the objects semantically related with the target itself.

The third aim of the study concerned the **nature of the visual features representation**: we would like to test the hypothesis whether the surface features can be considered part of the semantic knowledge of the object. In general, the facilitation effects due to the Identity Primes, especially in the experiments involving the verbal-targets (3.5.3 and 3.6.4), suggest that the aspects depicted by the primes can be recognized as part of the target-object. Furthermore, the emergence of interference effects due to the Same Category and the Different Category primes (in the Word Categorization and Picture-Word Compound Categorization experiments-3.5.3 and 3.6.4, respectively) reinforce the idea that a semantic activation is occurring (see above), in line with Glaser & Glaser (1989).

We previously discussed about the time required in order to solve the task (as function of difficulty), and we identified it as the crucial variable explaining the emergence of the priming effects for this or that category in the diverse conditions (see 4.8.1 -1-). In light with this interpretation, we can further suggest that the surface features are at first visually analysed and then, when time is given, they are recognized as part of the object and they give rise to the activation of the higher (semantic) representations. In fact, as previously commented, the prime effects can not be restricted to the structural description level, since they emerge also in the case of the verbal targets (i.e. the Word Categorization Experiment -3.5.3- and the Word-Picture Compounds Categorization Experiment -3.6.4-), where the shape-information is not presented.

We commented some studies in the literature, which in part sustain the idea of a semantic representation of the visual surface features of the objects, at least for what concerns the colour. In particular, Ostergaard & Davidoff (1985) showed that the colour dimension has little part in the object recognition, while it seems to have a crucial role in the object naming, speeding up responses for the coloured objects.

They interpreted their findings commenting that naming relies on the semantic activation and that it occurs at later stages of processing, at which the colour is combined with the shape information. In their opinion, at the early stages of processing the colour is treated quite independently from the shape, resulting in no influence on the object recognition. They concluded that colour is semantically represented, and (for this reason) it has differential effects on the diverse tasks. With respect to our hypothesis, the Ostergaard & Davidoff (1985) study gives some support to the idea that the surface features can activate upper representations than the "Structural Description".

However, in the Word-Picture Experiments (3.6.4, 3.7.3 and 3.7.4) we found facilitation effects for the Identity primes and interference effects due to the Same Category and the Different Category primes only when the colour and the texture dimensions are presented bound together. From this we concluded that the surface features are stored as a specific representation, and that the colour or the texture per se are not sufficient in order to activate the semantic representations of the objects, not in line with the previously reported study by Price and Humphreys (1989), who concluded that the texture can be considered a separate dimension from the colour.

3.8.3. Refining the model

In conclusion, our results seem to suggest that the visual surface features play a role in the object representation, at least in the case of two categories of objects –i.e. the fruits/vegetables and the animals-, which are strongly defined by them.

Moreover, we interpreted the time-dependent emergence of the priming effects in light of the hierarchical models of object recognition and representation (i.e.: Bussey and Saksida, 2002; Tyler et al., 2004). Furthermore and in light with the same models, we claimed that the surface features are possibly represented as a unique trace, comprising both the colour and the texture information. Finally, we concluded that the surface features can be considered as part of the semantic representation of the objects, since they can be recognized independently from the presence of the shape (i.e. line-drawings), they contribute in terms of facilitation in the tasks not relying on the structural description activation (i.e. the word classification) and they can give rise to the interference effects not explainable at the lexical level (Glaser & Glaser, 1989).

On the basis of such conclusions, we propose a refined version of the tentative models previously introduced (Figure 3 –paragraph 3.2.2), which is presented in

Figure 21. In this reviewed model, the early visual analysis allows the reconstruction of the Gross Structure of the object (in line with the Marr's model and its further developments –see Chapter 2), which is intended as the information needed by the cognitive system in order to access the Structural Description. When the Structural Description is matched in memory, the activation of the other details (such as the shape parts and the gross surface characteristics) is possible and required -maybe in a variable fashion- in order to achieve the complete object identification. The corpus of this information is sufficient, in any case, to access the semantic knowledge about the object (as represented by arrow ***a*** in the figure). However, the activation is supposed to spread towards the abstract information AND towards other visual information, achieving a more and more detailed trace, which is likely to be semantically represented. We assume that our primes convey such kind of information - corresponding to the finer details, the specific information about the colour, the fine surface features, and so on-.

It is worth noting that in our study such information is not activated by the shape presentation, but, on the contrary, it is presented as the prime *before* the shape or the word presentation (the target). We can assume that the activation can spread in the two directions, i.e. from the structural description level to the semantics *or* from the semantics to the structural description level (as represented by the two-direction arrows in the model). Furthermore, as concluded in our study, the visual surface features can be thought as part of the semantic memory, and can activate other semantic (abstract) information, needed, for example, when an intra-semantic classification has to be performed (such as in our experiments).

Thus, we can imagine that the visual surface features presented as primes in our experiments are recognized as part of the corresponding target objects, activating the semantic representation in a Visual Semantic space. The activation elicited within the Visual Semantics spreads then to the other levels, activating them, or sustaining their activation, that could has just occurred after the target presentation.

Thus, in the case of the ***Object Decision***, the prime is supposed to activate the corresponding Fine Surface Features component of the Visual Semantics; immediately after, when the target appears, the corresponding Structural Description is activated. We claim that, because of the spreading of activation from the Fine Surface Features to the Structural Description, some facilitation effects can arise during the task solving. This facilitation emerges only when the Fine Surface Features activated correspond to the target object.

Similarly, the activation of the Fine Surface Features occurring after the prime presentation can sustain the activation of the Structural Description in the case of the **Object Classification**. In this case, however, the activation of the Abstract Semantics is required in order to solve the task and we claim that it is supported by the activation that generates within the Fine Surface Features representations and spreads to the abstract semantics.

In the case of the tasks involving a verbal-target (i.e. the **Word Classification** and the **Word-Picture Compounds Classification**), we assume that the activation spreads from the Fine Surface Detail components (triggered by the prime presentation) to the Abstract Knowledge, reinforcing the activation of the Lexical Representations elicited by the target presentation.

In such a model, the colour and the texture of objects (at least in the case of the specific classes of objects here considered) are "doubly" represented: at the pre-semantic level they correspond to the gross representations, involving the prototypical information (i.e. yellow/black, stripes, for tiger), whereas at the semantic level the same information is stored in a more complex and refined way, with several dimensions bound together (as represented by the connection between the colour and the surface features in Figure 21).

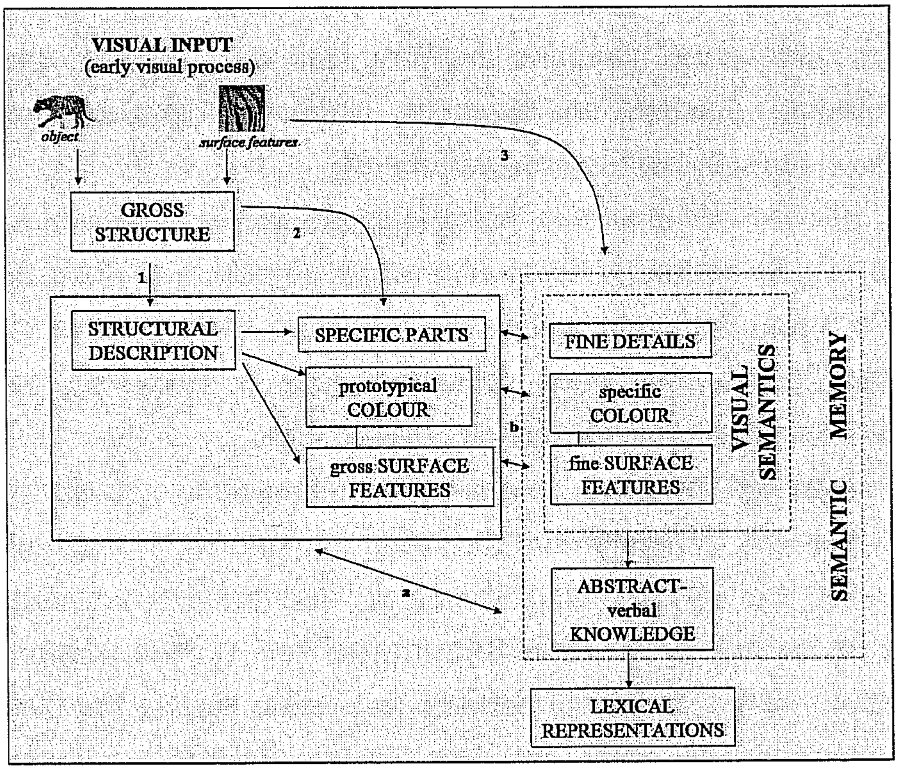

Figure 21. A tentative model of object representation.

Similarly, Ostergaard and Davidoff (1985) claimed that colour is semantically (verbally) represented, since it is a crucial variable in the naming tasks, while it has no effect on the other kinds of tasks, such as the object decision, the object classification and so on.

However, differently from those authors, we claim that colour[33] is mapped into the Structural Descriptions as a gross prototypical information about the object (i.e. *lemon → yellow*) AND it is specified as a detailed and more "realistic" feature at the semantic level (i.e. l*emon is yellow, where yellow is very clear/light etc.*)[34]. In other words, after the early visual processing, that takes place when a visual object is presented, more refined operations of identification of the object visual features are performed by the system. The gross information about colour (i.e. "it is red") are directly connected with the Structural Description and strongly contribute to the object identification. The other refined information, relative to the kind of colour, the presence of fine details of the surface and so on (i.e. "it is light red, with small black spots and variable areas of dark red) can be further added and matched with the stored knowledge in the Visual Semantics (i.e. Specific Colour, Fine Surface Features). Thus, the Visual Semantics, thought as part of a larger semantic system, is here assumed as the specific store in which the refined information about the visual appearance of the objects is represented. In particular, the memory traces about the visual surface aspect of the objects are represented as complex representations, resulting from the binding of several dimensions. The colour and the texture are supposed to be specified and bound in a unique representation in the Surface Features within the Visual Semantics, resulting in complex representations, which are supposed to be strictly defining for each individual object and not applicable to the other exemplars of the same category.

We claim that this model can fairly fit with the previously described positions about the functional organization of the occipito-temporal areas in the monkey (Bussey and Saksida, 2002) and with those derived from the normal and the pathological functioning in the human (Tyler et al. 2004 –but see next chapters for further comments).

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[33] But also other visual surface features, such as the texture.

[34] This idea was sustained by some data collected on the neuropsychological patients: see Chapter 4 for details.

4. Experimental part: Neuropsychological investigation

4.1. Introduction: Testing the semantic nature of the visual features in a damaged memory system

In the previous Chapter we addressed some questions about the nature of the surface features' representation in different kinds of priming studies. In this second part we would like to address the same questions using neuropsychology, that is, investigating the performance of patients who have a damage in the object representations or in their retrieval.

We had two alternative ways to approach this issue. The first was to study the behaviour of patients unable to access the stored representations about the shape of objects –i.e. agnosic patients-, in tasks requiring the managing and the access to the surface aspects employed in the priming experiments. The other way was to investigate the visual features' representations in patients who presented a deficit in the semantic system.

Humphreys, Riddoch & Quinlan (1988) presented a model for object representation derived from the observation of agnosic patients. This model assumes that object recognition takes place at different stages, including the perception of the physical sensory stimulus and the subsequent access to the stored Structural Descriptions.

It is commonly accepted that the Structural Description conveys the pre-semantic information about the perceptual features of the objects (including the shape, the parts and the details), whereas all the abstract information is supposed to be represented elsewhere (i.e. in the semantic system). According to this distinction, visual agnosia can be defined as a deficit in the visual recognition of the objects, whereas a semantic deficit implies the damage to the conceptual representations of the objects (not limited to one modality).

In this light, studying agnosic patients would be relevant, since they are supposed to show a deficit at the structural description level, whereas they could have good performance in the semantic memory tasks. Thus, if the visual surface features of objects are semantically represented, we would expect a quite good performance of such patients with this kind of material. On the other hand, the same subjects would be bad in the tasks involving the recognition of the object-shape.

However, patients with semantic problems would give us the opportunity to investigate our hypothesis at two levels. (1) If our hypothesis about the visual features (see 3.2.2) is correct, we would expect that semantic patients could be able to recognize the shapes of the objects -at least at the category level-, but unable to manage and retrieve the information about the visual features of the same items. (2) Furthermore, and as we will see, the semantic deficits observed in our patients are characterized by the so-called "living-non living dissociation", that is a different involvement of the living entities and the artefacts in terms of the knowledge loss. Such a phenomenon, well described in the literature, has been often interpreted as suggesting a differential role of visual attributes for the two main domains of knowledge (i.e. Living vs. Non Living Things). We assume that studying the patients with a dissociation between two domains of knowledge would be relevant in order to understand the role played by the visual aspects in defining these classes and, more in general, the nature of such features' representations.

4.2. Semantics: Neuropsychology and Category-Specificity

4.2.1. Category specificity as the empirical basis of the investigation of semantic memory

The largest part of the literature about the conceptual organization in the human is based on the investigation of neurological patients who present with a specific impairment of some categories of knowledge, while preserving the information about other categories. The most commonly observed phenomenon is the diverse impairment of the living and the non living things domains (see Capitani et al., 2003 for an exhaustive review), even if a dissociation between other kinds of material has been also observed (e.g. abstract vs. concrete words: Warrington, 1975, 1981; common vs. proper names: McKenna & Warrington,1978; nouns vs. verbs: McCarthy & Warrington, 1985). Even if cases exist of the selective impairment of the artefacts (Warrington & McCarthy, 1983, 1987; Sacchett & Humphreys, 1992; Hillis & Caramazza, 1991; Cappa, Frugoni, Pasquali, Perani and Zorat, 1998), the largest part of the category specificity patients show the sparing of the non living things' elements vs. the loss of living beings' knowledge.

Despite the existence of studies claiming that the semantic dissociations are spurious, there is large agreement in treating the phenomenon of the category specificity as a real effect, based on effective data[35].

As proposed by Capitani et al. (2003), the theories about the category specificity can be summarized in two main positions. The first kind of theories, referred to as "the correlated structure principle theories", are based on the idea that the brain organize the concepts according to the statistical occurrence of the categories' properties. The second kind of positions, "the neural structure principle theories" assume that the brain has some representational constraints, which can influence the way in which the information about the world is stored.

In the following paragraphs, after a brief description of the lesion localization in the category specificity-patients (see 4.2.1.1), we will present some of the theories within each main position (4.2.1.2), including the most recent attempts to solve the category specificity problem in more comprehensive accounts (4.2.1.3).

4.2.1.1. The locus of lesions determining semantic impairments and category specificity

The category specific deficits are associated with lesions in the anterior and medial temporal lobes, usually involving both hemispheres. The reviews of Living-Non Living dissociation cases (Gainotti, 2000; Capitani et al., 2003) evidence that the majority of patients with a selective impairment for biological entities shows the

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[35] It has been suggested that the Living-Non Living Thing dissociation can be explained by confounding factors, such as, for instance, the visual complexity (Steward, Parkin & Hunkin, 1992), the difficulty of the material (Gaffan & Heywood, 1993), and the lower word and concept frequencies. Moreover, Funnel & Sheridan (1992) hypothesized that the familiarity of the items would be the crucial factor in determining the semantic specific deficits. However, a large amount of works has been reviewed (Humphreys & Forde, 2001) in which the frequency and the complexity of the material have been checked in the statistical analysis, without vanishing the category-specific effects (i.e. Farah, Meyer & McMullen, 1996; Forde, Francis, Riddoch, Rumiati & Humphreys, 1997; Sartori, Job, Miozzo, Zago & Marchiori, 1993; Sartori, Miozzo & Job, 1993). Moreover, there are reports of patients presenting a semantic damage for categories of items they were supposed to be expert of (i.e. Sartori & Job, 1988, patient Michelangelo), and of patients who present semantic problems limited to the Non Living Things' category, despite the preservation of the Living Things exemplars (see, for example: Cappa et al. 1998; Hillis & Caramazza, 1991; Warrington & McCarthy, 1983, 1987).

involvement of the temporal cortices in the left hemisphere or bilaterally. In particular, Gainotti (2000) reported a detailed analysis of the lesion location in patients showing a Living Things' impairment: the study confirmed the existence of bilateral lesions, predominant in the left side, the prevalence of involvement in the anterior than in the posterior aspects of the temporal cortices, and the quite invariable involvement of the inferior aspects of the same lobes.

Capitani et al. (2003) reviewed a few cases of living things' domain impairment associated with frontal lesions.

In the neuropsychological literature several cases of living things' category damage have been described following HSE, deriving from both unilateral (left) and bilateral lesions (left lesions: e.g. Warrington & Shallice, 1984; Sartori & Job, 1988, Sartori et al. 1993; Tyler & Moss, 1997. Bilateral lesions: e.g. Sheridan & Humphreys, 1993, Barbarotto, Capitani & Laiacona, 1996)[36].

In a previously described work (see paragraph 2.4.3) Tyler et al. (2004) tested the hypothesis of a differential activation of the temporal areas, depending on the level of information required by a task (involving object processing); in particular, they argued that the temporal cortex is organized hierarchically and that the anterior regions are recruited in the fine-grained processing of visual objects. We also reported a more recent study by the same group (Moss et al. 2004), in which the authors proposed that the damage to the anterior and medial aspects of the temporal areas would determine the inability in the fine-grained processing required in semantic tasks involving in particular the living things' category, thus explaining the emergence of the dissociation effects. Despite in this view there is no clear differentiation between the form and the other visual aspects defining the objects, it appears plausible to think that the features required in the fine-grained tasks used in the study (i.e. naming at sub-category level –see 2.4.3 for details) would be not just the form attributes, but also some specific surface visual details.

4.2.1.2. "The correlated structure principle theories"

The seminal studies about category specificity dates back to the eighties: in their work, Warrington & Shallice (1984) studied 4 herpes simplex encephalitis patients, all presenting with a large damage to the temporal lobes (bilaterally). At the neuropsychological tests they all showed a disproportionate impairment of the Living

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[36] See Capitani et al. (2003) for an exhaustive review.

Things' knowledge, while preserving the opposite domain (artefacts). The authors excluded that the dissociation effect found in these patients could be due to familiarity or frequency of the material employed in the study, and they furthermore ruled out the possibility that the deficit would be caused by language or visual problems.

Further cases were found in the same period, who showed the opposite dissociation –i.e. preservation of the Living Things' domain vs. deficit in retrieving the information about the Non Living Things' classes (Warrington & McCarthy, 1983, 1987). These findings brought evidence in favour of the existence of a double dissociation between two domains, thus giving strong support to the authenticity of the category specificity effect[37].

Trying to explain the emergence of such effects, the authors observed that the living entities are usually defined on the basis of the visual information, whereas the artefacts and the objects are specified by their function. The difference between the categories of knowledge would be the counterpart of a specialization within the semantic system, which areas are specifically devoted in the processing of different kinds of instances (i.e. those depending on sensory knowledge vs. those defined by functional information). Furthermore, Warrington & Shallice (1984) suggested that a double representation of the visual information can exist within the system. They came to this conclusion after noticing that patients were highly consistent in their error-pattern and –crucially- this consistency was correlated with the input modality. For this reason, the authors suggested that the visual information can be duplicated and represented both verbally and visually, in two separate semantic systems. The development of SFT (Warrington & McCarthy, 1987) explicitly stated that different input channels give rise to separate semantic representations, coming out in separate sub-systems within memory. In such a view, knowledge about the living entities is supposed to be stored in "sensory" areas, whereas knowledge about the artefacts is assumed to be represented near the "functional" (motor) areas, so that the selective damage of the area devoted to one kind of information can determine a category-specific deficit. According to this position, we would expect that a patient with a living things' domain deficit would be low in retrieving sensory information about that class, whereas the patients showing the opposite dissociation (i.e. artefacts deficit) would be impaired in retrieving functional knowledge.

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[37] See Shallice (1988) for the role of the double dissociations in the neuropsychological studies.

4.2.1.3. "The neural structure principle theories"

The neural structure principle theories state that the semantic system is organized according to the information content (vs. information format), basing on the assumption that the evolutionary pressures, would have determined some neural constraints in the brain, favouring the emerging of specialized areas for particular kinds of concepts. In particular, Caramazza & Shelton (1998) proposed the Domanin-Specific account, according to which the categories of objects important for the human beings survival (such as the plants, the foods, the predators) would have received a particular attention within the system. In other words, the brain would have specialized anatomically on the pressure of these constraints, determining the emergence of areas for the animals-concepts, for the fruit&veg category and so on.

Evidence in favour of this position comes from the observation of refined fractionations within the system: in fact, there are reports of patients which are selectively impaired only for some sub-classes within the main domain of the living things or of the artefacts, i.e. the tools, or the fruits and vegetables, the animals (Santos & Caramazza, 2002, for tools; Farah & Wallace, 1992, Hart, Berndt & Caramazza, 1985, for living things sub-categories). According to these models, the emergence of such fine dissociations is not compatible with the hypothesis of a sensory-functional organization of the semantic system: in fact, if the patients loose, for instance, the visual information and preserve the functional knowledge about the objects, it is difficult to explain why a dissociation between the fruit&veg and the animals would occur.

4.2.1.4. Semantic memory as a unitary distributed system

A series of theories derive from the two main positions previously described, which tried to include the different cases in the literature in more comprehensive models. These theories take into account the inter-correlation between the characteristics which define the objects. Across them, for instance, the "OUCH" (Organized Unitary Content Hypothesis) developed by Caramazza et al. (1990) claims that all the concepts are organized in terms of their properties within the same multidimensional space. In this view, the semantic categories are differentiated with respect to the diverse density of intercorrelation between their defining attributes, so that the Living Things would correspond to the denser regions. Furthermore, the authors assume that the denser regions are more susceptible to damage, and this would explain the emergence of the semantic dissociation between living and non living things (that usually impairs the former category of objects).

Other accounts take into consideration the intercorrelation between the concept properties and the specific categories. For instance, both De Renzi & Lucchelli (1994) and Tyler & Moss (1997) emphasized the fact that the function is strongly correlated with the form of the objects: a hammer has a particular shape, which allows to handle it and to use it to hit nails, whereas a different form would not allow to employ it for the same purpose. Buxbaum & Saffran (1998) subsequently specified the "function" introducing the idea of the "manipulability" of the objects: that is, the form of the object allows to handle and to manipulate it in a certain way. The motor patterns associated with the manipulation correspond to the activation of the fronto-parietal areas and would be the critical dimension in defining the artefacts' category.

As a development of these accounts, Tyler, Moss, Durrant-Peatfield and Levy (2000) argued that, within the attributes of a concept, the less vulnerable to damage are those which are strongly correlated each other. In the case of the artefacts, the function of the objects become crucial, and it is stored in a strict association with some form-features: these attributes become "distinctive" for the artefacts. In the same logic, the living things are defined by some perceptual characteristics, which are shared by quite all the members of the category and are linked with the general biological function of the class. In the authors view, the distinctive features and the shared attributes are the less vulnerable to damage and this would explain the different patterns of deficit observed for the two classes of objects in the literature.

Humphreys & Riddoch (2003; but see also Humphreys & Forde, 2001) proposed a model for object recognition - HIT (Hierarchical Interactive Theory) – in which the early visual processing of the objects is followed by the access to the structural descriptions, which would in turn gains the semantic information or the lexical instances, in a cascade fashion. The model assumes that the category specific effects are due to the different level of structural similarity of the diverse classes of objects. As previously put forward by Humphreys & Riddoch (1987), contrary to the artefacts, the living things category is characterized by a high degree of visual similarity between the exemplars (in terms of the shape appearance)[38]: the major amount of structural similarity in the case of the living things would explain the so often observed selective impairment for this class. Contrary to other positions, the HIT proposes that the category specificity can emerge for a problem in the shape

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[38] For other works by the same authors based on the "structural similarity" idea see paragraph 2.2.4.

processing or to a deficit in the structural description retrieval. The basic assumption is that the semantic information is stored in a different level of representation, and concerns only functional information about the objects (vs. visual information). Thus, patients with problems at the structural description level would be agnosic, but they will not present with a semantic impairment; conversely, it is not necessary that patients with semantic deficits have problems with the visual appearance of the objects whereas they are supposed to be impaired in the retrieval of the functional and abstract information about the objects. The HIT doesn't exclude that the semantic system is categorically organized (in line with Caramazza & Shelton, 1998), and that semantic dissociations can emerge for specific impairments at this level (i.e. deficit in retrieving the functional information for the artefacts).

In summary, for this account, semantic dissociations can occur for a problem at the pre-semantic level –due to the major vulnerability of some classes of objects characterized by higher degrees of structural similarity- or at a semantic level –due to the conceptual fractionation of the store-.

4.2.1.5. Other distributed accounts

The just described Convergence Zone Theory (Damasio, 1989; Tranel et al. 1997; see paragraph 2.3.5) fits with the idea of a unitary conceptual system, in which the object-representations correspond to patterns of activation of cross-modality feature maps, which are hierarchically organized along the sensory-motor areas. As we have seen, the features maps correspond to a neural activity (the so-called conjunctive neurons): these can be modality dependent (at early stages of the hierarchy) or across modalities (at higher levels of representation).

Starting from this model, Simmons & Barsalou (2003) developed a comprehensive account, that specifies in detail the organization of the convergence zones and the conjunctive neurons in the brain. Crucially for the topic of this chapter, the authors proposed the so-called "similarity in topography principle", according to which the categorical structure of the world directly derives from the topography of the associative areas in the brain:*"[...] As two sets of conjoined features become more similar, the conjunctive neurons that link them lie closer together in the CZ's (convergence zones) spatial topography"*. This means that when an element is perceived, a distributed pattern of activation occurs, involving some crucial features which are clustered together (but not in a strictly localized fashion). As a consequence, the categories of objects are the result of a distributed pattern of activation and the exemplars of the same category are supposed to activate feature maps which overlap and are closely distributed. Though the high detail with which Simmons & Barsalou described their model, with particular reference to the nature of the feature maps and the convergence zones, we report here only some main points that we consider important for our purposes. (1) Quite interestingly these authors argued that, contrary to what sustained by Damasio (1989), the feature maps can be thought as representational instances, which can also be activated in the absence of a bottom-up stimulation. This means that the feature maps can be re-activated in tasks requiring the retrieval of the concepts and not only the visual processing of actual stimuli. (2) The neural localization of the modality specific feature maps fits with the previously discussed positions of Tanaka (1996 –see paragraph 2.3.2) and Tyler et al. (2004 - see 2.4.3). (3) The authors proposed that the damage to a specific kind of feature map or convergence zone[39] can determine a precise deficit in a brain damaged patient. In particular, the emergence of category specific deficits can be ascribed to the damage to a visual feature map, that determines a problem in the visual processing (visual agnosia) and, in turn, the selective losing of the categories of items strongly defined by visual aspects (i.e. the animals). The damage to the so-called analytic convergence zones, which combine information about a specific kind of features (coming from different feature maps), can determine a problem in retrieving the specific properties common to different categories of objects. Crucially, the authors commented that the contemporary lesion to the animals and the fruit&veg categories, which can be problematic for some theories about the semantic system organization, can derive from the damage to a common convergence zone relative to a particular property (e.g. visual attributes). The authors further discussed the emergence of modality-specific single-category deficits (e.g. patients with deficits in retrieving visual information for the animals category only), and explained these patterns as the result of a selective damage to a modality convergence zone that combines the visual information of animals. Simmons and Basalou further discussed two controversial findings in the category specificity literature. In detail, they explained the relative infrequency of the non living things damage as the result of the diverse degree of dispersion of the feature maps for the different categories; moreover, the existence of convergence zones combining the visual properties for a specific category can explain the emergence of the simultaneous loosing of visual

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[39] The authors assume the existence of modality-specific, emotional and motor features maps; moreover, they describe analytic, holistic, modality and cross-modal convergence zones.

information and artefacts knowledge (vs. preservation of the living things' class). Finally, the damage to the "cross-modal" convergence zones can explain the existence of categorical deficits, which were previously used by other authors in order to sustain the idea of a specific conceptual fractionation of the semantic system (see 4.2.1.2).

4.2.2. Does a visual semantic system exist?

With respect to the central issue of our work, which is the way in which specific visual features are represented, few of the studies previously reported clearly distinguish between the different role of shape vs. surface properties of objects, commenting about the possible existence of a visual semantic system, that would be depositary of some perceptual information different in content or in format from the structural description store.

With respect to the main models of semantic memory, the HIT proposes a strict differentiation between pre-semantic perceptual information and semantic non-perceptual knowledge stores, whereas the SFT sustains the idea of a separate representation of visual information within the semantic system.

The authors who developed the SFT, in the seminal investigations reported in 4.2.1.2, not only assumed a separate representation of the perceptual attributes within the semantic memory, but they made also an explicit reference to the specific visual properties we are interested in (i.e. the colour, the texture, the surface properties). In particular, Warrington & Shallice (1984) clearly referred to some specific visual properties which are crucial in defining -for instance- the fruits and vegetables: "*to distinguish between a strawberry and a raspberry depends critically upon fine difference in colour, shape, size and texture* (p. 849). Similarly, Warrington & McCarthy (1987) commenting about the differential weight of the visual features for some categories of objects, specifically distinguished between colour and shape information ("*within the visual channels, colour rather than shape is the critical attribute*", p. 1291). These studies did not consider in detail the relationship between the structural description level and the semantic memory, but they came to the conclusion that the visual information is semantically represented, and that it concerns not only shape-form attributes, but also the visual specific properties like the colour, the texture, the pattern of the surface of the objects and so on.

The same authors presented the case of a patient who had a worse performance in tasks testing his visual knowledge about the same items he was able to name on verbal description (Warrington & McCarthy, 1994). The difficulty of this patient were restricted to the living things domain elements, and this, in the authors' view, corroborated the hypothesis of the existence of a multiple semantic system, including a verbal and a visual part.

Coltheart, Inglis, Cupples, Michie, Bates and Budd (1998) took into account the issue of the distinction between the content of the structural descriptions vs. the (possible) semantic visual system. These authors conducted an electrophysiological study and an investigation on a patient (who suffered from a stroke in the territory of the middle cerebral artery), which came to similar findings. With particular respect to neuropsychological study, the authors found that the patient had a preserved knowledge for non visual attributes of objects (encyclopaedic, functional and also auditory/olfactory information), whereas he had a bad performance with visual properties, independently from the modality of access. The authors proposed a model for object representation in which each kind of perceptual information is represented in a separate subsystem. All these components are in turn separate from a central non perceptual knowledge store, but in communication with it. Coltheart et al. (1998) admit a categorically fractionation of the central system, similarly to Caramazza & Shelton (1998), but -contrary to them- the authors propose that the perceptual systems are unitary and not fractionated on the basis of the category of belonging of the concepts. They try to explain the emergence of category-specific effects arguing that the selective loss of an instance in the non-perceptual store can determine a general category specific deficit, since top-down support to the (unitary) perceptual systems is not still allowed. Coltheart et al. (1998) propose that the visual knowledge system is used for both the recognition and the information retrieval about the object, thus indirectly suggesting that it is both pre- and semantic in nature. As abovementioned, the authors suggest a separate representation for the different modality-specific perceptual information, so that a visual, an auditory, an olfactory and a tactile knowledge system are supposed to exist. However, they do not make clear distinction between the specific kinds of visual information, with the exception of the size-information, which is assumed to be a non-perceptual attribute.

In their review, Capitani et al. (2003) reported the existence of patients which are impaired in both the object decision, which is the task that reveals the possible presence of a damage to the object form representation (structural description) and in tasks requiring the verbal retrieval of visual properties (visual semantics). However, other patients are reported who show the preservation of the structural descriptions vs. a selective loss of visual (semantic) information and who show the damage to the structural descriptions and both the visual and non-visual semantic information. The possible independence of damage to the structural description system and the visual attributes' retrieval in some patients has be interpreted as the proof of the autonomy of the two stores. As pointed out by Capitani et al., two cases of categorical damage (for living things) to both the structural description system and the visual semantics have been reported (Sartori & Job, 1988); these cases have been interpreted as the needing of an intact structural description system in order to have an intact visual semantic system (at least for the living things' class). Sartori & Job thus favoured the hypothesis of a structural description system which is depositary of the visual information about the objects, and which is recruited by a non-visual semantic system when a verbal task requires visual information in order to be solved.

More recently, Warrington & Crutch (2004) described a patient with a semantic refractory access dysphasia, who presented a clear-cut dissociation between the performance in verbal and visual associative tasks. In detail, the patient was had an inconsistent performance at different presentations of the same material in picture-word matching tasks, whereas he was consistent when the material was purely visual (i.e. picture-picture matching tasks). The authors, basing on the assumption that "visual-visual matching of structurally dissimilar objects having the same name or function access a semantic representation", interpreted their results in favour of the existence of a separate store for verbal and visual representations within the semantic system. It is worth noting that the authors clearly described the patient's abilities in visual processing and object recognition on one side, and the ability to associate different exemplars of the same object on the other, thus excluding any confusion between the structural description and the visual semantics.

4.2.3. On the role of the visual attributes for particular classes of objects

The role of the visual semantic features in defining specific classes of objects was firstly taken into consideration in the seminal works by Warrington & Shallice (1984) and Warrington & McCarthy (1987). As previously discussed, these authors explained the occurrence of deficits for particular classes of the living things (and some non living things as well) as due to the difficulty of the patients in retrieving fine-grained sensory information, including the shape, the colour, the details of the object surface, etc. As previously reported, they brought the example of the fruits and vegetables' category, which elements are all similar in their gross shape and their function; the elements of this category thus need of the discrimination of the finer visual aspects (colour, texture, details of the surface) in order to be distinguished one each other. Therefore, in this view the role played by the visual features is crucial in the representation of some classes of objects, whereas it seems to have a minor part in the representation of other categories (such as, for instance, the artefacts).

We have previously commented the positions of De Renzi & Lucchelli (1994), Tyler & Moss (1997), Tyler et al. (2000), Buxbaum & Saffran (1998), about the role of the perceptual and the functional attributes in defining the diverse semantic categories (in paragraph 4.2.1.3). Crucially, when speaking about perceptual features, all these authors concentrate mostly on the shape-dimension: the artefacts are defined by the function associated with the form-characteristics linked to it; the living things are characterized by shared perceptual features, which define the gross biological function of the living beings. However, the specific visual properties of the objects (such as the colour, the texture and the surface properties) are not taken into account in a specific way, or at least as a piece of information which is different from the form-dimension.

Finally, in the neuropsychological investigation on their HSE patients, Borgo & Shallice (2001, 2003) concentrated on a different category of elements, that is the "mass kinds" (i.e. foods, textiles, liquids, edible substances, metals and materials etc.). The mass kinds are a peculiar class of objects, since they are strongly defined by their sensory aspects, but they all lack the shape dimension: for these characteristics, they would behave similarly to other living things classes, which representations are supposed (by the SFT) to strongly rely on sensory aspects.

The patients studied by Borgo & Shallice, presenting a living-non living dissociation (in favour of the non living things) were impaired in retrieving information about the living things categories and, crucially, they showed deep difficulties in managing the mass kinds' knowledge. The authors concluded that this can be interpreted as a proof in favour of the SFT, since the impairment in the stored sensory determined a damage to another category, which exemplars are strongly defined by such information.

4.2.4. Comments on the category specificity and the visual features status in the literature

(a) In summary, different theories try to explain the emergence of specific semantic deficits in neuropsychological patients, paying particular attention to the phenomenon of the category specificity. These theories consider in turn the categories of knowledge as the result of evolutionary pressures on the brain (which determine a neural structural substrate for the different classes), or the result of a specialization of the system for different kinds of information (i.e. sensory information, crucial for the living things vs. functional information, crucial for the artefacts). Other accounts propose an intercorrelational approach, stating that different kinds of features are associated in a diverse fashion within the two main domains of knowledge.

(b) The areas of the brain which are mainly involved in the emergence of the category specific deficits are the temporal lobes, often bilaterally. Some recent studies have tried to find finer specializations with the occipito-temporal stream: whereas the occipital areas and the posterior aspects of the temporal lobes are dedicated to the gross analysis of objects, the anterior-medial aspects of the temporal lobes have been identified as the areas devoted to the fine-grained discrimination processes and thus activated for the living things, which strongly rely on specific perceptual attributes).

(d) With respect to the visual features representation, the majority of the reported studies, when speaking about the visual attributes of the living and the non living things, concentrates on the form and shape aspects, or, when the issue of the role of the more refined visual features is taken into account, no clear distinction between surface and form attributes is made. Some exceptions are the studies of Warrington & McCarthy (1987) and Borgo & Shallice (2003) who explicitly stated that the living things and other similar categories of items behave in a similar fashion because of their strong dependence on visual features such as form, but also colour and texture.

Moreover, we argued that the Tyler et al. position (2004) can fairly fit with the idea that the visual attributes re-activated in the anterior-medial areas of the temporal cortex would ~~be form+surface~~ refined properties of objects.

(f) However, maybe because of a problem in the definitions of the terms, the issues about the existence of a semantic visual system and its content are still under debate. As previously reported, Coltheart et al. (1998) posed the problem of the representational status of the form, the size and other kinds of visual information, hypothesizing that the each different kind of perceptual information (differentiated by input modality) is stored separately from the other (functional and encyclopaedic) properties. Crucially, according to these authors, the visual information corresponds to the structural description, so that the same store is affected in patients showing agnosia or semantic visual deficits[40]. Similarly, Sartori & Job (1988), making some comments on the arising of category specific deficits, proposed that the semantic system re-activates visual information from the structural description, which is depositary of a complete visual representation of the objects and mediates the verbal production of visual features.

(g) Recent accounts for object representation, such as the Damasio's convergence zone theory (1989) and the Simmons and Barsalou's position (2003) propose more comprehensive models, which explain the emergence of category specific deficits on the assumption of a distributed representation of properties and categories within the occipito-ventral stream.

In conclusion, the neuropsychological investigation reported in the literature seem to support the idea that the information about the form of the objects is represented at a pre-semantic level (structural descriptions), whereas other kinds of properties (i.e. colour, texture, surface details) have been alternatively referred to as pre-semantic or semantic information. Particular interest have been posed in the colour-status, whereas less clear is the real nature of other kinds of visual information, such as texture and surface details. Despite some attempts to define the representational status of some specific kinds of visual properties, this matter seems to remain unsolved and, crucially, no studies in the literature consider in an explicit way the representational status of the visual surface features studying the behaviour of the neuropsychological patients.

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[40] Even if with some specifications –see the original paper.

4.3. The neuropsychological investigation

4.3.1. The aims of the healthy subjects' investigation applied to the patients

The healthy subjects' study described in the previous chapter had three aims: (1) to investigate the possible contribution of the visual surface aspects in object recognition; (2) to test the possibility of an activation of such features independently from the structural description; (3) to understand the nature of the visual surface features representation, testing the idea that they are stored within the semantic memory.

On the basis of the priming and interference paradigm experiments we concluded that the visual surface features play a strong role in object recognition, that these features can be activated and recognized independently from the shape-dimension (structural description) and, crucially, that it is plausible to think that colour and texture of objects are semantically represented bounded, as a unique semantic attribute of the object.

In this chapter we aim to test these statements on patients, presenting them with some tasks requiring the recognition of the objects and the surface aspects or the association between the surface features with the objects (or the corresponding words). We would like to test the three main aims in the following way.

(1) The contribution of the visual surface features in object recognition can be tested comparing patients performance in tasks involving the same objects, presented with or without the crucial features (i.e. coloured pictures vs. black and white picture vs. line drawings) - Naming of objects (4.4.2), Matching tasks involving objects (4.4.3 and 4.4.4). The finding of a facilitation effect due to the presence of the surface features would be interpreted as a proof of the crucial role of these attributes in object recognition and representation. Since we are investigating patients behaviour, we could not exclude that the facilitation is general, due to the larger amount of information given in the stimuli. In order to contrast this hypothesis, the comparison between Naming and association tasks (which are supposed to be easier) would be critical. The possible absence

(2) The hypothesis of **a separate representation of structural descriptions and visual surface features** can be confirmed, in our opinion, by the possible observation of different performance of patients with object recognition-processing vs. visual features (presented isolate) identification –identification of isolate visual features (4.5.2, 4.5.3, 4.5.4), comparison between object and feature processing (4.5.5), and comparison between verbal and visual tasks (picture-picture tasks, 4.5.5.4);

(3) in general, the semantic nature of the visual features representation can be inferred by the patients' performance across all the presented tasks: the two cases here studied show semantic degradation, whereas they can not be considered agnosic. In other words, we can affirm they are able to recognize objects, without problems at the structural description level, whereas they have a deficit at the semantic system level. Thus, a problem in the visual features recognition can't be ascribed to a visual processing or to an agnosic problem (see, in particular, Naming Tasks: Details -4.5.2- and matching tasks involving details -4.5.3, 4.5.4); on the contrary, a bad performance with such material can be interpreted as a consequence of the semantic system degradation.

The results of the neuropsychological study will be discussed in light of the three main hypothesis and further commented trying to fit the patients' pattern of performance with the model of object representation proposed in paragraph 3.8.3.

4.3.2. The neuropsychological cases

We had the opportunity to study two Herpes-Simplex Encephalitis patients. As described in paragraph 4.2.2, the HSE pathology, often disrupting the temporal lobes, is usually associated with semantic memory deficits and in particular with the Living-Non Living Dissociation. Both the patients here described present with a large damage of the temporal lobes bilaterally and they both show a semantic memory degradation.

The first patient's damage dates back to 1994, but his deficits are still very deep. His general neuropsychological profile has not changed during the years, evidencing a clear-cut Living-Non Living dissociation with a high degree of consistency in the performance across the different sessions of testing. The second patient presents a shorter neuropsychological history (she was injured in 2001), associated with a good level of recovery and a very good general cognitive profile. She presented a clear-cut Living-Non Living dissociation after illness; her performance is continuously improving, even if refined paradigms and highly specific tasks still show at present the endurance of some semantic deficits.

4.3.3. Case 1: MU

4.3.3.1. Clinical history

MU is a 40-year-old man, with 13 years of schooling. He was a plumber before his illness. In 1994, after an episode of feverish and mental confusion, he became comatose and was admitted to the hospital, where a diagnosis of Herpes Simplex Encephalitis was posed. He was feverish for about two months and needed ventilation for the time he was comatose (about two weeks). He was promptly treated with Acyclovir and he came out of the coma state in April 1995.

4.3.3.2. Neuropathology

The CT scan showed a severe cortical damage, mainly localized in the right hemisphere.

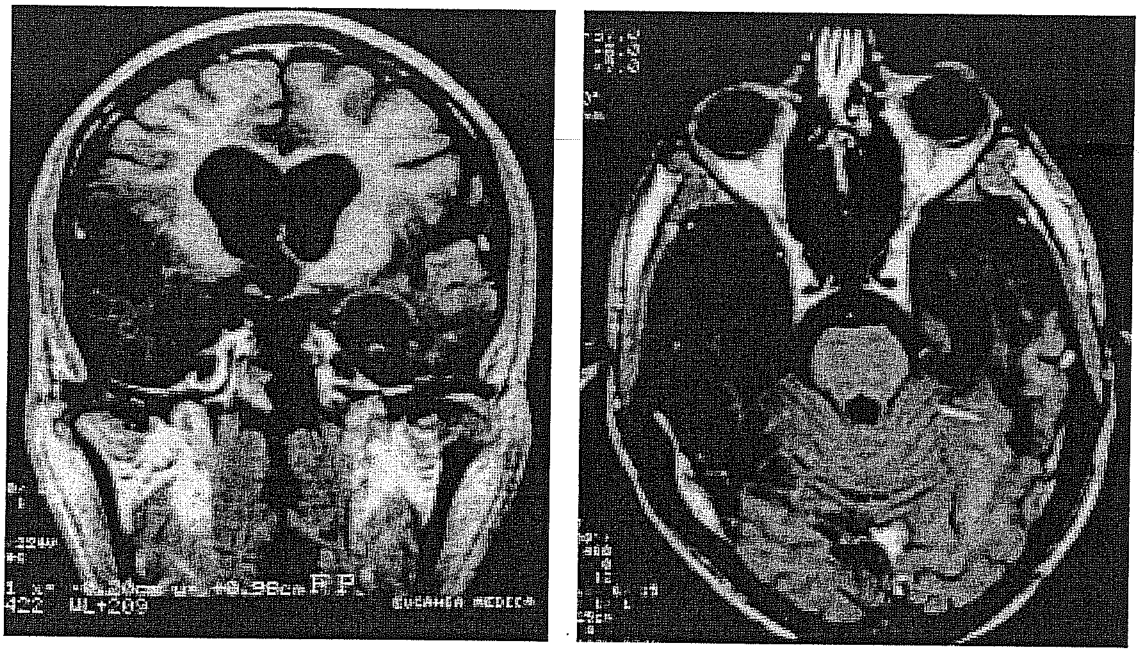

Figure 22. MRI scans of MU: on the left, the coronal section; on the right, the horizontal section (in each scan, right is left and vice versa).

The lesion involved the external capsule, the left peri-sylvian areas, and the temporal lobe; a minor involvement was observed in the frontal lobes bilaterally and in the superior areas of the parietal lobe on the left side. The MRI scan showed some areas of damage in the temporal lobes bilaterally and in the medial portions of the frontal lobes (see Figure 22). The right occipital lobe was injured in the medial portion. The EEG showed the typical alterations caused by HSE: diffuse activity with theta and delta waves, which recovered only in the left hemisphere.

4.3.3.3. Neuropsychological profile

The patient underwent a complete neuropsychological assessment in April 1995, after he came out the comatose state. He presented severe deficits, in a wild range of cognitive domains (see the Appendix C, Table a,b); in a large set of semantic tasks MU showed a strong semantic deficit, mainly involving the Living Things category, and sparing the Non Living Things (Appendix C-Table c): this deficit emerged in all the tasks presented, including Naming on Visual Confrontation, Naming on Verbal Description and Matching Tasks. He was also impaired in the tasks requiring the answering of questions about the attributes of the items. Moreover, the analysis of MU's performance revealed quite better results when he features had to be retrieved, than when sensory information was needed.

A wild range of cognitive abilities were assessed in a second session of evaluation, dated 2003-2004 (for details see the Appendix D-Table a). MU showed to be quite consistent in his performance after 2 years, showing, again, an IQ below the normal range his Performance IQ was below the normal mean, while his Verbal IQ was not calculated, since the patient was defective in the majority of the sub-tasks used to estimate the verbal component of intelligence. He was not perfect at the Raven Progressive Coloured Matrices as well. His Digit Span Forward was within the normal range, while he was impaired in the short-term memory tasks (Story Recall) and the working memory (Digit Span Backward). His general attentive and planning abilities were quite good (i.e. Visual Search, Elithorn's Test), while he was impaired in the tasks requiring a high degree of monitoring and attentive control (i.e. Trail Making Test A and B). His verbal fluency was deeply impaired.

Visual abilities and recognition MU was good in the general perception tests (Hishiara test: colour naming; see Appendix D- Table b), while he showed some problems with the De Vreese et al. Battery for Colour Perception, where he was impaired in associating the correct colour to the objects, in the wrong-colour recognition tests and in the fluency for diagnostic-colour categories of objects.

He was severely impaired in the Benton's Face Recognition Test, evidencing prosopagnosia. When tested on recognition abilities (BORB, VOSP see the Appendix D, Table b), MU showed good general perceptual abilities, with the exception of some specific sub-tests (Length matching task and Position of gap matching task), in which he was below the normal range. However, he showed a high level of impairment in the object recognition (BORB: Object Decision, Associative Matching and Naming tasks; VOSP: Silhouettes, Progressive Silhouettes), evidencing some specific difficulties in object-shape processing and structural description retrieval.

Language abilities MU's language abilities were investigated through the BADA battery[41] (see the Appendix D, Table c): MU was quite good in all the comprehension tests, comprising the auditory and the visual comprehension of nouns and verbs, the grammatical comprehension on visual and auditory presentation. He showed a normal or rather-normal performance in tasks of general verbal production (description of pictures and scenes visually presented). His naming performance was quite good when the items were verbally defined by the examiner, while it was clearly impaired on the visual presentation (both nouns and verbs).

Semantic impairment and category-specificity Table 3 reports the patient's performance at the Laiacona et al. battery (Laiacona, Barbarotto, Trivelli and Capitani, 1993), showing his error-rates for the individual sub-categories.

	Naming	**Intra-category comprehension**	**Inter-category comprehension**
Total	**27/80**	**1/80**	**3/80**
Animals	4/10	0/10	1/10
Vegetables	8/10	0/10	1/10
Fruits	5/10	1/10	0/10
Parts of the body	1/10	0/10	0/10
Tools	2/10	0/10	0/10
Furniture	1/10	0/10	0/10
Vehicles	0/10	0/10	0/10
Musical instruments	4/10	0/10	1/10
Living Things^1	**17/30**	**1/30**	**2/30**
Non Living Things^2	**3/30**	**0/30**	**0/30**
Asymmetry index	**0.37***	**0.02**	**0.03**

Table 3. MU's performance at Laiacona et al. Battery ^{1} Without Parts of the Body; ^{2} without Musical Instruments; * index indicating an asymmetry in favour of Non Living Things (better performance). The raw scores refer to number of errors.

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[41] Batteria per l'Analisi dei Deficit Afasici. G.Miceli, A. Laudanna, C. Burani, R. Capasso, CESPAG (1994).

MU had difficulties in Naming on visual presentation (27/80 errors), while he was good in the comprehension tasks (Intra- and Inter-Category matching tasks).
The error amount was larger with the Living Things (17, 1, 2 errors in Naming, Intra- and Inter-Category Comprehension, respectively) than with the Non Living Things (3, 0, and 0 errors in Naming, Intra- and Inter-Category Comprehension, respectively).

4.3.4. Case 2: SER

4.3.4.1. Clinical history

SER is a right-handed 29-year-old woman, with 17 years of schooling. In 2001 she was concluding her University degree master when she was hospitalized after an episode of feverish and mental confusion. After the clinical examination a Herpes Simplex Encephalitis diagnosis was posed on March, 2001 and the patient was then treated with Acyclovir. At the de-hospitalization, SER appeared soon very collaborative and conscious of her cognitive impairment, even if some behavioural mild abnormalities were evident until July, 2001 (slight dysphoria, bizarre behaviour). Her relatives observed severe memory problems and some difficulties in planning and problem-solving, quite evident in the everyday life; they also reported marked difficulties in visual recognition of common objects and familiar faces. After few months (September 2001), she appeared much improved with respect of her behavioural problems and visual recognition difficulties; moreover, she used spontaneous and successful strategies to compensate for the learning and memory problems.

4.3.4.2. Neuropathology

A CT scan performed immediately after the hospitalization showed hypodense lesions in the right temporal regions, in the right frontal areas (with a probably involvement of the controlateral regions as well) and in the right occipital region. A MRI scan (June, 2001) showed a diffuse and marked alteration of the signal in both the cortical and the sub-cortical regions (see Figure 23). Some irregularities were found in the sub-cortical white matter in the frontal lobes (more marked on the right side, corresponding to the right internal capsula), and in the peri-ventricular parietal and the occipital areas on the right.

The temporal lobes showed irregularities of the signal on both sides (including the left corona radiate and the left semioval nucleus); in detail, in the right temporal areas the MRI showed an alteration of the signal in the cortex, in the corresponding sub-cortical white matter and sub-cortical level.

A cavity of para-encephalic type was found in the deep right temporal areas, in the proximity of the anterior temporal horn of the lateral ventricle. A diffuse leucomalacia, involving the sub-cortical and the cortical layers and mainly observed in the temporal lobes, was compatible with the sequelae of the herpes simplex encephalitis infection.

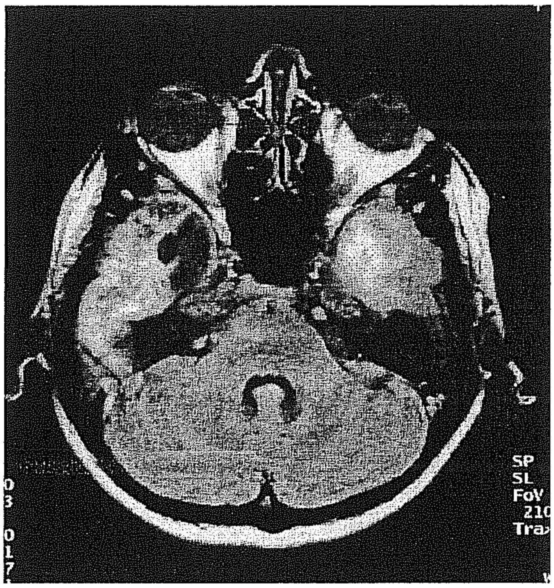

Figure 23. MRI scans of SER: the horizontal section (right is left and vice versa).

4.3.4.3. Neuropsychological profile

SER's neuropsychological profile was assessed for the first time from April to June 2001: she showed diverse cognitive problems, including reasoning, planning and attention deficits, which are shown in Appendix E. In particular, she was defective in some semantic tasks, such as the Naming on Visual presentation (with respect to both the Living and the Non Living Things, even if the level of impairment was greater for the Living Things); when presented with verbal definitions, SER showed the same pattern of performance, but only for the definitions relying on sensory aspects. In the comprehension tasks she was quite better and her performance was within the normal range with the artefacts, but below the normal mean with the Living Things.

General cognitive profile- second assessment At the time of the experimental investigation, SER's general performance was good, and she showed to be improved with respect to the first neuropsychological evaluation. In detail, she had a good performance in the attention and planning tests and no problems in abstract thinking and reasoning (see the Appendix F).

	Naming	**Intra-category comprehension**	**Inter-category comprehension**
Total	**6/80**	**0/80**	**0/80**
Animals	1/10	0/10	0/10
Vegetables	1/10	0/10	0/10
Fruits	0/10	0/10	0/10
Parts of the body	0/10	0/10	0/10
Tools	2/10	0/10	0/10
Furniture	1/10	0/10	0/10
Vehicles	0/10	0/10	0/10
Musical instruments	1/10	0/10	0/10
Living Things[1]	**2**	**0**	**0**
Non Living Things[2]	**3**	**0**	**0**
Asymmetry index	**0.03**	**---**	**---**

Table 4. SER's performance at Laiacona et al. Battery

[1] Without Parts of the Body; [2] without Musical Instruments; * index indicating an asymmetry in favour of Non Living Things (better performance). The raw scores refer to number of errors.

Despite her superior-to-average results in the digit span forward, she showed an impaired performance in the digit span backwards and other memory measures of the Wechsler Memory Scale (Information, Orientation, and Associative Memory). With respect to her visual recognition abilities, SER was clearly better than in the first session of assessment at the VOSP (none of the sub-tests were below normal range), whereas she had a bad performance in a visual recognition task (Embedded Figures Recognition).

Semantic impairment and category-specificity SER showed no problems with specific semantic tests (Laiacona et al. 1993), revealing a quite complete recovery from her semantic impairment. The formal tests failed to reveal a dissociation between the Living and the Non Living Things (see Table 4)[42].

4.3.5. Summary and patients' comparison

In summary, the two patients present with the same pathology (HSE), which determined cortical lesions with similar localization (i.e. the temporal areas, bilaterally or predominately on the right side) that is compatible with the literature reports about the living-non living dissociation and with the more recent comprehensive hypothesis about the temporal lobes functional organization (e.g. Tyler et al. 2004). Both MU and SER showed an initial deep cognitive impairment, relative to diverse functions (i.e. reasoning, attention, memory abilities); in particular, they both showed a strong semantic deficit, with a clear cut dissociation between the living and non living things categories (in favour of the non living things). With time, one of the patients (SER) came to a quite complete recovery of the general cognitive profile and of her semantic problems, even if the qualitative observation showed an endurance of slight deficits involving the living things' category. The other patient (MU) showed a stable profile across the different sessions of testing, showing a clear cut semantic dissociation effect.

Despite the presence of the semantic deficit in both MU and SER, we can not ignore that both the patients show a deficit in object recognition as well: this renders less clear the nature of their deficit, and does not allow to exclude an agnosic problem is at the basis of their difficulties. However, their recognition problem was actually circumscribed to very specific tasks, in which the explicit identification of the objects was required; most importantly, they showed more difficulties with the visual descriptions of objects than with the functional ones, and also more problems with the verbal descriptions relative to the living things category than to the artefacts class. Thus, we argue that the visual recognition deficits in these patients are linked to a more general semantic deficit, that determines a difficulty in managing some categories of objects and in retrieving specific information about the items. Anyhow, the first part of the experimental study on the patients aims to clearly describe the nature of their semantic deficit and, in particular, the differential involvement of diverse classes of objects (see next section).

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[42] For a more extensive investigation of SER semantic abilities, see Borgo & Shallice, 2003.

4.4. Experimental investigation on the patients: the Living and Non Living Things visual tasks

4.4.1. General aim of the experiments

The aim of these experiments was to investigate MU's and SER's ability to recognize the items taken from different categories and to process their specific knowledge about them. We wanted to know whether a dissociation effect between the two main categories of interest (Living vs. Non Living Things) existed and if any of the sub-categories used in the study (see later) was selectively impaired with respect to the others.

In order to do this, we used different Living Things' and Non Living Things' sub-classes. Within the Living Things, we used both the animate (Animals, Birds, Small Animals&Insects) and the inanimate (Fruits&Vegetables, Plants&Flowers) entities. Within the Non Living Things we utilized two "standard" sub-categories of items, which are usually employed in the semantic investigation studies (i.e. Tools and Musical Instruments) and we introduced two "new" sub-classes (i.e. "Textiles" and "Balls") which were supposed to be strongly defined by their visual features. The "Textiles" corresponded to a series of clothes and textile-made objects (i.e. *tablecloth*, *carpet*), which were selected because of their typical high-recognizable surface properties, such as the colour and the texture pattern. For example, a *"sweater"* is easily recognizable from its shape (a "T", with long arms, a short and large stem, a hole on the top), but it also presents a typical wool-pattern[43]. For this reason, we assumed that the textiles could be used as a control category for the Living Thing sub-classes, which items are often defined by both the shape characteristics and their surface features[44].

We are aware of the different weight these aspects could play in defining the Textiles or the Living Things: the Textiles colour-texture aspects are quite variable and arbitrary, while the natural items are defined by their surface aspects in a 1:1

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[43] We selected the items for which the change in pattern would create a "strange" and quite un-recognizable object: i.e. a smooth surface would be an atypical feature for the *"sweater"*.

[44] Consider, for example, the Birds: most items of this sub-category share the same shape-structure, while they can be distinguished on the basis of the colour pattern of the surface. Moreover, a lot of 4-legged animals can be differentiated by the colour and the texture pattern (lion vs. tiger) and the same is true for the Flowers and most of the Fruits and Vegetables.

relation. However, we would like to test the hypothesis that these surface aspects could be selectively lost in the HSE patients, even if in different degrees across the diverse categories considered. Moreover, we decided to introduce a further Non Living Things class - i.e. the "Balls" - in order to obtain a control-category for the fruits and vegetables. This "control" sub-category was chosen since both the *fruits* and the *balls* are typically rounded-shaped and their surface properties (the colour and the texture pattern) strongly contribute in distinguishing their exemplars (see Warrington & McCarthy, 1987).

In this first part of the chapter we describe the performance of the two patients' in some tests tapping the knowledge about the global appearance of the items. In the second part (4.5) we will concentrate on some experiments intended to explore the specific knowledge that MU and SER have about the surface aspects (i.e. colour and texture) of some of the categories used in the study.

4.4.2. Naming tasks

4.4.2.1. Specific aim of the task

Naming is a useful task, since it allows to test the general recognition abilities and, being usually assumed to involve the semantic access (see, for instance, Humphreys et al., 1988), it can evidence semantic deficits and the possible dissociation effects between the different categories. For these reasons, we presented both the patients with a naming task involving items taken from the Living and the Non Living sub-categories previously introduced. Moreover, varying the quantity of visual information given (i.e. presenting coloured, black and white or line-drawing pictures) we could investigate the role played by colour and texture in the recognition and the representation of objects, and thus partially test the first aim of the study (see paragraph 4.3.1).

4.4.2.2. Methods

Materials The Naming task involved 5 Living Things' sub-categories (Animals, Birds, Small-Animals&Insects, Fruits&Vegetables, and Plants&Flowers) and 4 sub-classes belonging to the Non Living Things (Tools, Musical Instruments, Textiles and Balls). Within the Living Things, the Animals and the Birds comprised 28 and 24 items, respectively; the Small-Animals&Insects comprised 18 items (13 insects and 5 small animals[45]); the Fruit&Veg category consisted in 21 items (15 fruits and 8 vegetables), while the Plants&Flowers comprised 8 plants/trees and 10 flowers. Within the Non Living Things, we used 22 Tools, 23 Musical Instruments and 11 Balls; the Textiles sub-category comprised 19 items, 9 of which were household objects and 10 consisted in clothes. A complete list of the items for the different sub-categories is reported in the Appendix G).

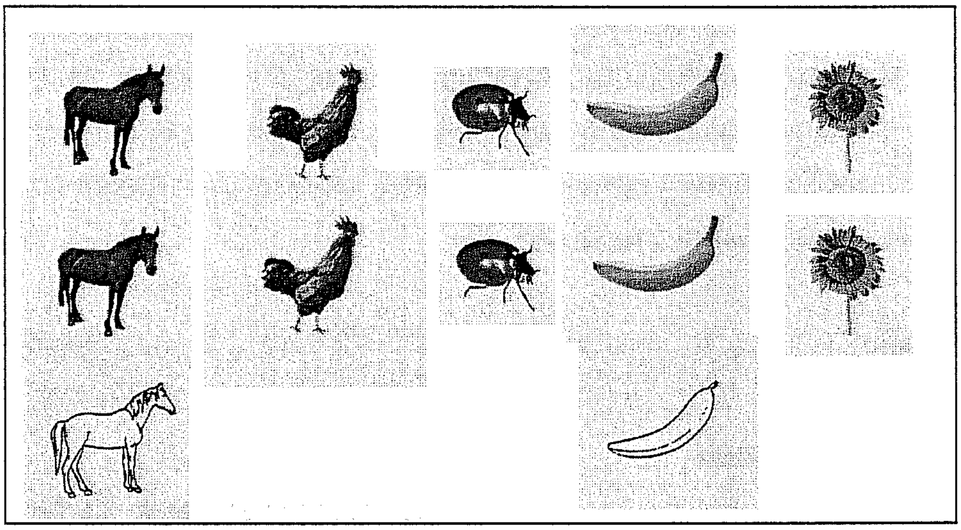

Figure 24. Examples of the items belonging to the Living Things domain. The 5 columns represent _Animals', Birds', Small-Animals&Insects', Fruits&Vegetables' and Plants&Flowers' items, respectively. The rows report the coloured, the black&white and the line-drawing pictures, respectively.

We created a coloured and a black-and-white version of each item of each sub-category (see Figure 24 and 25); moreover, for the sub-classes crucial for the study (i.e. Animals and Fruits&Vegetables) items were also presented as line-drawings (Figure 24). The line-drawings were derived from the Snodgrass and Vanderwart's set (1981) or obtained from other sources (books, copyright-free websites), trying to match the visual properties of the Snodgrass and Vanderwart's ones.

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[45] The Small Animals consisted in entities such as the *snail*, the *spider* and the *worm*, which are not insects, but which sizes are quite comparable with those of the insects.

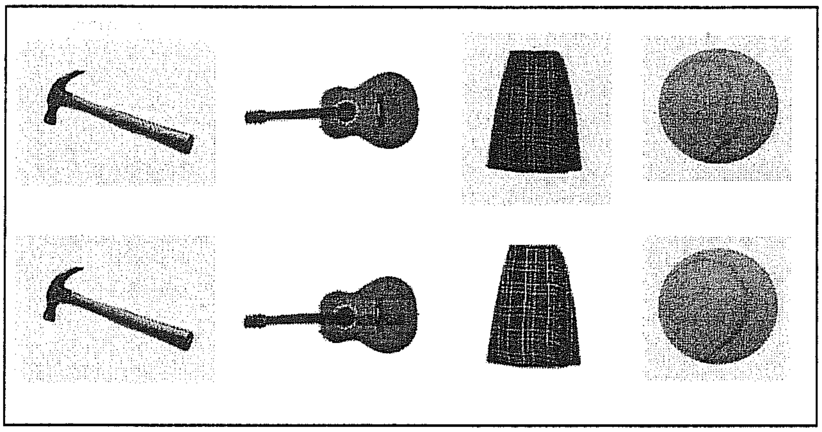

Figure 25. Examples of the items belonging to the Non Living Things domain. The 4 columns represent Tools', Musical Instruments', Textiles' and Balls' items, respectively. The rows report the coloured and the black and white pictures, respectively.

Procedure All the pictures (matched for size and luminance) appeared on a computer screen through an E-Prime Study@. The sub-categories were presented separately, during different sessions of assessment; moreover, it never happened that the same sub-category was presented in the coloured, the black and white and the line-drawing version during the same session. For all the categories, each picture lasted on the screen until the response was given and the examiner pressed a keyboard button in order to pass to the next presentation.

Control subjects Each patient was compared with a different group of healthy subjects, matched for age, education and sex. Being the same material employed in different tasks (see later: 4.4.3, 4.4.4), the Naming and the Matching tasks were divided in blocks, trying not to include in the same block the same kind of material. In this way, different subjects were presented with different tasks.

4.4.2.3. Results

Living Things

MU's performance was severely impaired, being well below the range of his control subjects for all the considered sub-categories with both the coloured (see Table 5) and the black-and-white stimuli (Table 6).

	Naming: Living Things					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Animals (Col)	**0.43**	0.96 (*0.02*)	*-29.50 p<.0001*	**0.82**	0.97 (*0.03*)	*-4.48 p<.0001*
Animals (Bw)	**0.36**	0.99 (*0.02*)	*-35.50 p<.0001*	**0.82**	1.00 (*0.00*)	*pathological*
Birds (Col)	**0.09**	0.78 (*0.12*)	*-5.55 p<.0001*	**0.30**	0.79 (*0.09*)	*-5.68 p<.0001*
Birds (Bw)	**0.10**	0.78 (*0.16*)	*-4.32 p<.0001*	**0.31**	0.76 (*0.14*)	*-3.15 p<.001*
Small Animals&Insects (Col)	**0.16**	0.91 (*0.04*)	*-20.74 p<.0001*	**0.50**	0.84 (*0.12*)	*-2.82 p<.005*
Small Animals&Insects (Bw)	**0.06**	0.77 (*0.16*)	*-4.28 p<.0001*	**0.75**	0.84 (*0.9*)	*-0.92*
Fruit&Veg (Col)	**0.43**	0.96 (*0.04*)	*-13.39 p<.0001*	**0.81**	0.93 (*0.03*)	*-4.33 p<.0001*
Fruit&Veg (Bw)	**0.38**	0.93 (*0.05*)	*-11.50 p<.0001*	**0.81**	0.91 (*0.02*)	*-4.90 p<.0001*
Plants&Flowers (Col)	**0.17**	0.69 (*0.10*)	*-5.48 p<.0001*	**0.47**	0.90 (*0.09*)	*-4.56 p<.0001*
Plants&Flowers (Bw)	**0.00**	0.64 (*0.19*)	*-3.41 p<.0001*	**0.50**	0.80 (*0.15*)	*-2.00 p<.05*

Table 5. Accuracy proportions for MU, SER and their control subjects in the Naming Task (Living Things).

SER was impaired in all the sub-categories of Living Things for both the coloured and the black-and-white stimuli (Table 5). Her performance was quite good (even if defective when compared with the normal controls) with the Fruit&Veg and the Animals in the colour conditions; moreover, her accuracy was at the same level of the control subjects with the Small Animals and the Insects in the black-and-white condition (Table 5).

Only the Animals and the Fruits&Vegetables were presented as line-drawings (Table 6): both MU and SER were largely impaired with both the categories, even if SER performed better than MU (around 80% and 70% correct with the Animals and the Fruit&Veg, respectively).

	Naming Living Things: Line Drawing Items					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Animals	**0.52**	--	--	**0.79**	0.99 (0.02)	*-10.82* *p<.0001*
Fruit&Veg	**0.29**	--	--	**0.71**	0.91 (0.07)	*-2.89* *p<.005*

Table 6. Accuracy proportions for MU, SER and their control subjects in the Naming Task (Living Things).

Non Living Things

In the colour condition MU was impaired with respect to his control subjects' group for all the Non Living Things' subcategories (see the Table 7), even if a qualitative difference in terms of accuracy was observed for the Tools and the Textiles (60% and 68% correct answer, respectively). SER was impaired with respect to her control subjects as well, and this was true for all the sub-classes belonging to the artefacts domain (see Table 7). However, and similarly to MU, she was moderately better in naming the Tools and the Textiles items, even if her performance was still defective.

	Naming: Non Living Things					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Tools (Col)	**0.60**	0.95 (*0.04*)	*-9.55* *p<.0001*	**0.62**	0.96 (*0.03*)	*-13.7* *p<.0001*
Tools (Bw)	**0.77**	0.97 (*0.04*)	*-4.44* *p<.0001*	**0.73**	0.87 (*0.07*)	*-2.12* *p<.05*
Musical Instruments (Col)	**0.17**	0.94 (*0.06*)	*-12.81* *p<.0001*	**0.29**	0.91 (*0.10*)	*-6.10* *p<.0001*
Musical Instruments (Bw)	**0.24**	0.85 (*0.05*)	*-13.32* *p<.0001*	**0.52**	0.88 (*0.05*)	*-6.56* *p<.0001*
Textiles (Col)	**0.68**	0.97 (*0.03*)	*-9.53* *p<.0001*	**0.79**	0.97 (*0.03*)	*-6.21* *p<.0001*
Textiles (Bw)	**0.58**	0.93 (*0.07*)	-5.35 *p<.0001*	**0.74**	0.87 (*0.03*)	*-4.75* *p<.0001*
Balls (Col)	**0.30**	0.84 (*0.09*)	*-6.21* *p<.0001*	**0.36**	0.80 (*0.04*)	*-10.82* *p<.0001*
Balls (Bw)	**0.09**	0.89 (*0.05*)	*-17.50* *p<.0001*	**0.36**	0.89 (*0.10*)	*-5.31* *p<.0001*

Table 7. Accuracy proportions for MU, SER and their control subjects in the Naming Task (Non Living Things).

The same pattern of results was found for both the patients when the black-and-white stimuli were presented (see Table 7). Again, both MU and SER showed a higher accuracy with the Tools and the Textiles, but their performance was defective with respect to their control subjects for all the sub-categories considered.

4.4.2.4. Comment to the Naming Tasks

In summary, with a unique exception[46], both MU and SER were strongly impaired in the Naming tasks, irrespectively from the category of belonging of items (Living vs. Non Living Things). However, an advantage in terms of accuracy was observed for both the patients when the Non Living Things' items were presented and SER showed a better performance than MU with the Fruit&Veg and the Animals sub-categories. These results confirm the existence of a semantic impairment in both the patients, more evident in the case of the Living Things' sub-categories.

Moreover, no gross differences emerged comparing the different kinds of material presented (i.e. coloured, black and white, line-drawing items): this suggests that the colour and the texture pattern information is not useful for these two patients in order to obtain a better performance. With respect to the first aim of the study, this seems not to support the idea that colour and texture are crucial for the object recognition.

4.4.3. Picture to Word Matching Tasks

4.4.3.1. Specific aim of the task

The matching tasks aimed to exclude that the effects found in the naming study can be partly due to anomic difficulties; moreover, we assumed the picture-word association tasks would give insight about the nature of the semantic deficits, clarifying whether they are due to the degradation of the memories or to problems in accessing the semantic system. In this session we describe a task in which the same pictures used in the Naming were presented together with the corresponding word and other 3 alternative nouns: the patients were required to identify the word corresponding to the picture between the 4 alternatives. A good performance for all the categories is expected if the patients present mere access or anomic difficulties.

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[46] SER was at the same level of her control subjects with the Small Animals and the Insects category, for the black and white items.

4.4.3.2. Methods

Materials The same items employed in the Naming tasks were used here. The pictures were presented together with 4 words, comprising the target word and 3 distracters belonging to the same sub-category. The distracter words were chosen according to a similarity degree (for both the semantic and the visual dimensions), so that the first word represented an object very similar to the target (i.e. *lion* → *tiger*), the second word represented an object quite similar (i.e. *lion* → *cat*) and the third word corresponded to a completely different item (i.e. lion → *monkey*). The words (in capital letters, Times New Roman font) were displayed under the picture in a random array, so that in each presentation the target-word appeared in a different position (see Figure 26).

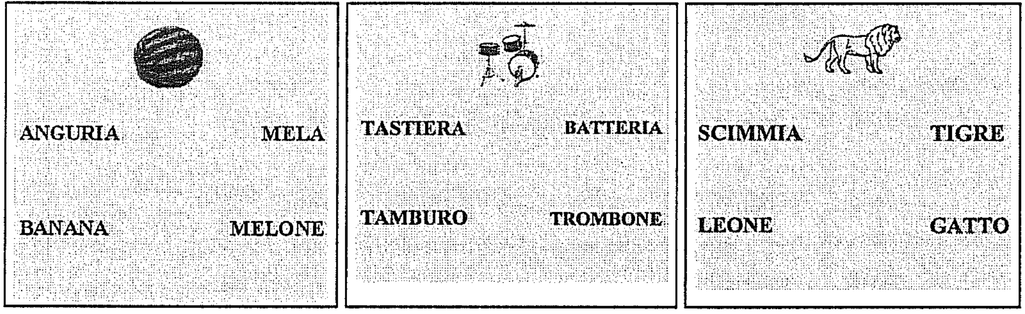

Figure 26. Examples of the Picture-to-Word Matching Task items. From left to right, a coloured picture belonging to the Fruit&Vegetables, a black and white picture belonging to the Musical Instruments and a line-drawing item taken from the Animals sub-class.

Procedure The pictures appeared on a computer screen thorough an E-prime study©, and lasted until the response was given. The subjects were instructed to associate the picture with the corresponding word, choosing one of the 4 given alternatives. The healthy subjects and SER were asked to press one of 4 indicated buttons on the keyboard in order to give their responses; being MU unable to properly use the keyboard, he was asked to indicate the correct word on the screen or to read it aloud, and the examiner pressed the buttons instead of him. The accuracy was collected for both the patients and their control subjects.

Control Subjects Both MU and SER were compared with a separate group of control subjects, matched for age, sex and education.

4.4.3.3. Results

Living Things

When compared with his control group, MU was impaired in the Picture-to-Word Task (coloured items) with respect to all the sub-categories considered (see the Table 8). Despite SER was well above chance (25% correct) with some sub-classes (i.e. Animals: 93% correct, Fruit&Veg: 90% correct), her performance was still defective with respect to her control subjects for all the sub-classes considered, with the exception of the Small Animals (see Table 8).

	Picture-to-Word Matching Task: Living Things					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Animals (Col)	**0.64**	1.00 (*0.00*)	*pathological*	**0.93**	0.99 (*0.02*)	*-2.92* *p<.005*
Animals (Bw)	**0.64**	1.00 (0.00)	*pathological*	**0.82**	0.98 (0.02)	-8.03 p<.0001
Birds (Col)	**0.46**	0.93 (*0.06*)	-7.50 p<.0001	**0.63**	0.88 (*0.07*)	-3.79 p<.0001
Birds (Bw)	**0.38**	0.89 (0.08)	-6.19 p<.0001	**0.58**	0.93 (0.05)	-7.37 p<.0001
Small Animals&Insects (Col)	**0.56**	0.90 (*0.05*)	-6.53 p<.0001	**0.61**	0.87 (*0.16*)	-1.60 p=.055
Small Animals&Insects (Bw)	**0.50**	0.90 (0.13)	-3.05 p<.0001	**0.61**	0.82 (0.06)	-3.47 p<.0005
Fruit&Veg (Col)	**0.62**	0.99 (*0.02*)	-17.44 p<.0001	**0.90**	0.99 (*0.02*)	*-4.02* *p<.0001*
Fruit&Veg (Bw)	**0.62**	1.00 (0.00)	pathological	**0.81**	0.94 (0.04)	-3.35 p<.0005
Plants&Flowers (Col)	**0.44**	0.93 (*0.05*)	-9.14 p<.0001	**0.67**	0.90 (*0.08*)	-2.83 p<.005
Plants&Flowers (Bw)	**0.39**	0.88 (0.12)	-3.95 p<.0001	**0.72**	0.86 (0.03)	-4.38 p<.0001

Table 8. Accuracy proportions for MU, SER and their control subjects in the Picture-to-Word Matching Task-Living Things.

MU was impaired for all the sub-categories considered in the Black-and-White version of the task and no gross differences in terms of accuracy were observed with respect to the colour version of the tasks (Table 8).

SER showed a defective performance in all the black-and-white conditions when compared with her control group (see Table 8); moreover, a slight decrease in accuracy was observed with respect to the colour version of the same task; however, she was still above chance with the Fruit and Vegetables and the Animals. For the line-drawing items (Table 9) MU was defective for both the Animals and the Fruit and Vegetables' categories; SER was impaired with the Animals' sub-class (even if her performance was well above chance), whereas her performance was comparable to her control group with the Fruit&Veg.

In general, a clear difference among the 5 sub-categories of the Living Things emerged at a qualitative observation (i.e. better performance with Animals and Fruit&Veg), as it will be further described in the next paragraphs.

	Picture-to-Word Matching Task -Living Things: Line Drawing Items					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Animals	**0.42**	...	...	**0.82**	0.98 (*0.03*)	*-4.92* *p<.0001*
Fruit&Veg	**0.29**	...	...	**0.90**	0.93 (*0.04*)	*-0.67*

Table 9. Accuracy proportions for MU, SER and their control subjects in the Picture-to-Word Matching Task-Living Things.

Non Living Things

MU was impaired with respect to his control subjects for quite all the Non Living Things' sub-categories, in both the colour and the black-and-white version of the task (Table 10). He was at the same level of the control subjects only with Tools' sub-category, in the colour version of the Picture-to-Word task (z=-1.41, see Table 10).

	Picture-to-Word Matching Task: Non Living Things					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Tools (Col)	**0.96**	0.99 *(0.02)*	*-1.41*	**0.84**	0.99 (0.02)	*-6.26* *p<.0001*
Tools (Bw)	**0.74**	1.00 (0.00)	*pathological*	**0.91**	0.97 (0.05)	*-1.1*
Musical Instruments (Col)	**0.36**	0.97 *(0.04)*	*-13.84* *p<.0001*	**0.55**	0.93 (0.11)	-3.35 p<.0005
Musical Instruments (Bw)	**0.45**	0.95 (0.04)	*-13.47* *p<.0001*	**0.55**	0.91 (0.07)	*-5.06* *p<.0001*
Textiles (Col)	**0.74**	1.00 *(0.00)*	*pathological*	**0.84**	0.99 (0.02)	-6.26 p<.0001
Textiles (Bw)	**0.68**	0.97 (0.03)	*-9.53* *p<.0001*	**0.84**	0.93 (0.08)	*-1.06*
Balls (Col)	**0.18**	0.98 *(0.05)*	*-17.50* *p<.0001*	**0.45**	0.87 (0.10)	*-4.03* *p<.0001*
Balls (Bw)	**0.27**	1.00 (0.00)	*pathological*	**0.55**	0.85 (0.05)	*-6.21* *p<.0001*

Table 10. Accuracy proportions for MU, SER and their control subjects in the Picture-to-Word Matching Task -Non Living Things.

SER was defective with both the coloured and the black and white items (Table 10). However, a clear difference in terms of accuracy was observed across the 4 sub-categories, with a clear advantage, for both the patients, in the case of the Tools and the Textiles (see next paragraphs for analysis).

Comparison between the sub-categories: MU

We performed comparisons across each sub-category within and across the Living and the Non Living Things' main classes; we report here only the more relevant findings, whereas a complete list of the comparisons is reported in Appendix H.

Since the control subjects were at ceiling in quite all the conditions, we could not rule out effects of difficulty for MU, who was impaired in most of the tasks. For this reason, we decided to restrict the discussion to the comparisons performed within groups of conditions in which the control subjects performed at the same level. We considered three groups of tasks, in which the control subjects were "at ceiling", "very good" and "quite good", respectively, but at the same level with the tasks within the specific group. The grouping of tasks according to control subjects' performance s is summarized in Figure 27.

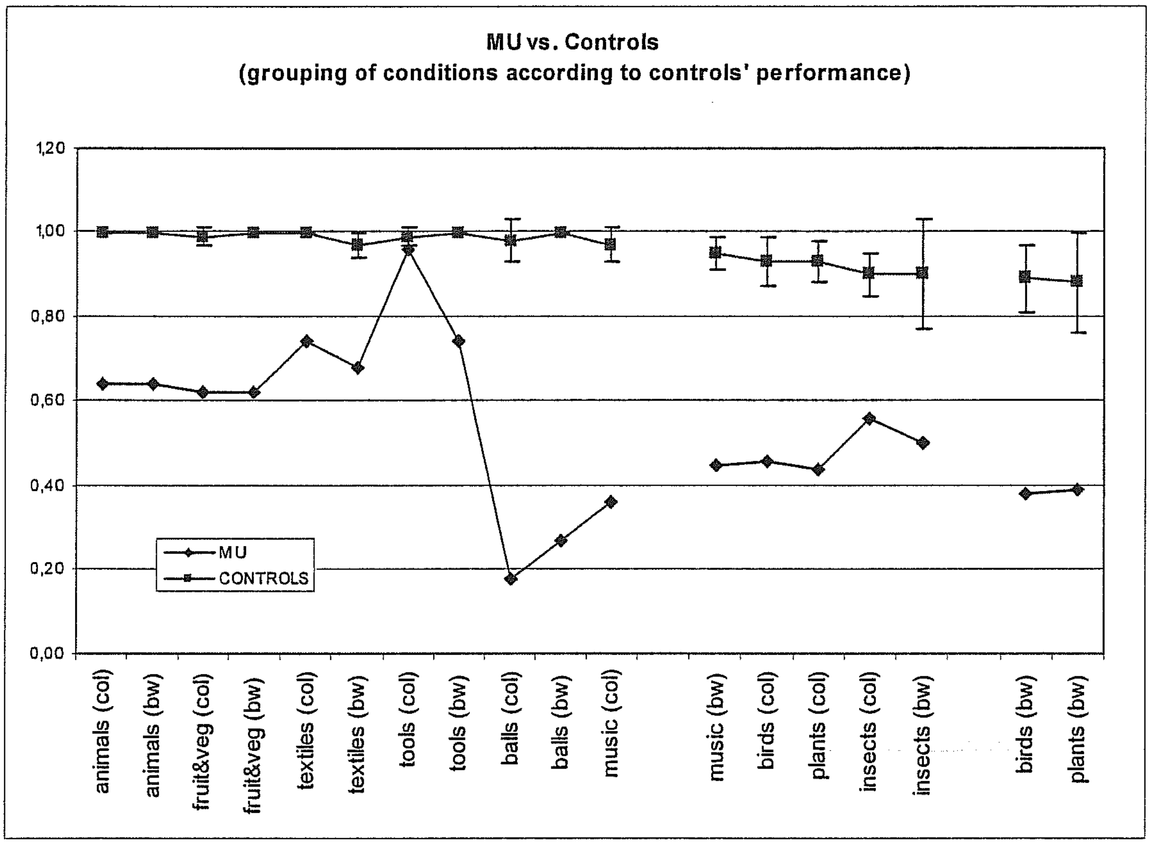

Figure 27. Summary of Picture to Word tasks: conditions are grouped on the base of the controls' performance level (i.e. ceiling, very good and medium performance, represented by the first, the second and the third group of tasks on the x-axis, respectively).

MU was **at the same level with all the Living Things sub-classes**, in both the colour and the black-and-white versions of the Picture to Word task. As a main result, MU showed a general advantage with the **Tools** over the other sub-categories belonging to both the Non Living Things and the Living Things domains. In particular, for the coloured stimuli MU's accuracy was higher with the Tools than with the Textiles (χ^2=6.32, *df*=1, p<.01), and than all the Living Things' sub-classes (Tools-Fruit&Veg: χ^2=10.44, *df*=1, p<.001; Tools- Animals: χ^2=9.42, *df*=1, p<.001). This general advantage disappeared for the black-and-white stimuli. The **Textiles** behaved as an "intermediate" category: it was in similar levels of accuracy than the Fruit&Veg (χ^2=.82, *df*=1, p=.18, *n.s.*) and the Animals (χ^2=.46, *df*=1, p=.25, *n.s.*) in the colour condition; in the black-and white condition the Textiles were at the same level of the Fruit&Veg (χ^2=.31, *df*=1, p=.29, *n.s.*), the Animals (χ^2=.19, *df*=1, p=.33, *n.s.*), the

Small Animals (χ^2=.47, *df*=1, p=.26, *n.s.*) and, within the Non Living Things domain, equal to the Tools (χ^2=.44, *df*=1, p=.27, *n.s.*). In the other cases the Textiles were generally better than the other sub-categories.

Comparison between sub-categories: SER

In order to exclude difficulty effects, the same procedure used for MU was applied in the case of SER (see above): a summary of the performance of SER and her controls is reported in Figure 28.

Within the Living Things sub-categories, SER showed to behave **at the same level with the Fruit&Veg and the Animals**, in the colour condition (χ^2=0.08, *df*=1, p=.40, *n.s.*). With the black-and-white stimuli, SER showed no gross differences between the Fruit&Veg/the Animals and the other sub-categories of the Living Things. In general, no differences emerged between the Birds, the Plants and the Small Animals, with few exceptions.

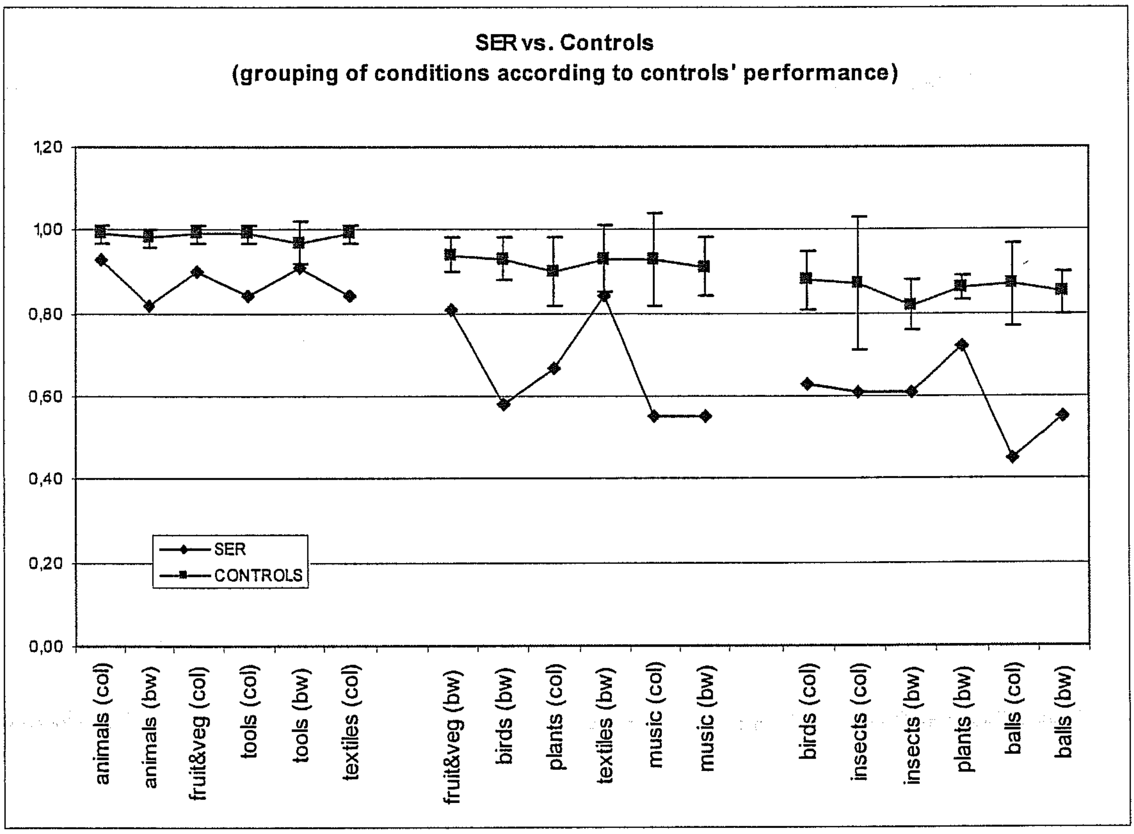

Figure 28. Summary of Picture to Word tasks: conditions are grouped on the base of the controls' performance level (i.e. ceiling, very good and medium performance, represented by the first, the second and the third group of tasks on the x-axis, respectively).

SER showed **no differences in accuracy between the Tools and the Textiles** being these two sub-categories usually associated with better results than the other classes. However, contrary to MU, SER showed no general advantages for the Tools over the Living Things' sub-classes, with the exception of the Birds in the black-and-white condition (χ^2=5.37, *df*=1, p<.01). The Textiles behaved similarly to the Animals and the Fruit&Veg in the colour condition, and to the Fruit&Veg and the Birds in the black-and-white condition.

Generally, no differences emerged between the other Living and Non Living Things' sub-classes, with some exceptions for the black-and-white stimuli: the Small Animals were better than the Balls (χ^2=3.35, *df*=1, p<.05) and the Plants were better than both the Musical Instruments and the Balls (χ^2=4.54, *df*=1, p<.05 and χ^2=7.47, *df*=1, p<.01, respectively).

4.4.3.4. Summary of the Picture to Word Tasks

Both MU and SER had an impaired performance with the Living Things, irrespectively from the sub-category of belonging of the items and the kind of material presented. The only exceptions were found in the case of SER, who performed at her control group's level with the Small Animals and the Insects (colour version of the task, Table 8) and with the Fruit and Vegetables' sub-category, when the items consisted in line-drawings (Table 9). With respect to the Non Living Things, the patients were impaired for both the colour and the black and white versions of the task, with the only exception of MU, who performed at the same level of his control subjects with the Tools (coloured items- Table 10).

The specific comparison across the sub-categories revealed some particular patterns of performance for both the patients, which can be summarized as follows:

MU-

(1) no differences emerged across the Living Things sub-categories;

(2) a general advantage was observed for the Tools category over the other artefacts (colour conditions) and over the Living Things' categories (more in the colour conditions);

(3) the Textiles behaved as an "intermediate" category: they were worse than the Tools but better than the other artefacts in the colour condition, whereas they were associated with similar accuracies to the coloured living things' sub-classes;

(4) the "new" Balls' sub-category was associated with a very bad performance.

SER-

(1) The Fruit and Vegetables and the Animals behaved similarly to the Tools and the Textiles, in particular in the colour conditions;
(2) despite the direct comparisons were not considered in the discussion, the qualitative observation showed that SER was better with the Tools and the Textiles, than with other non living things' categories;
(3) there was no advantage of the Tools over the Textiles;
(4) as observed for MU, SER's performance was very bad with the "new" artefacts' sub-category (i.e. Balls), even if it was not possible to compare this category with other sub-classes.

4.4.4. Word to Picture Matching Tasks

4.4.4.1. Specific aim of the task

This task aimed to investigate the patients' ability to access the object visual representation (pictures) starting from an abstract input (word). The same abilities investigated in the previous task, where a picture had to be matched with the corresponding word, are supposed to be required here. However, the underlying process could be quite different in a Word-to-Picture Matching, since the meaning has to be accessed from the word and the structural description of the object has to be represented and matched with one of the given alternatives only in a second moment.

4.4.4.2. Methods

Materials The same items employed in the previous experiments were used. Each trial consisted in a word and in four pictures taken from the same sub-category, representing the target-word and three other objects (see Figure 29). The distracters were the same used in the Picture-to-Word Matching task (but displayed in a different order).

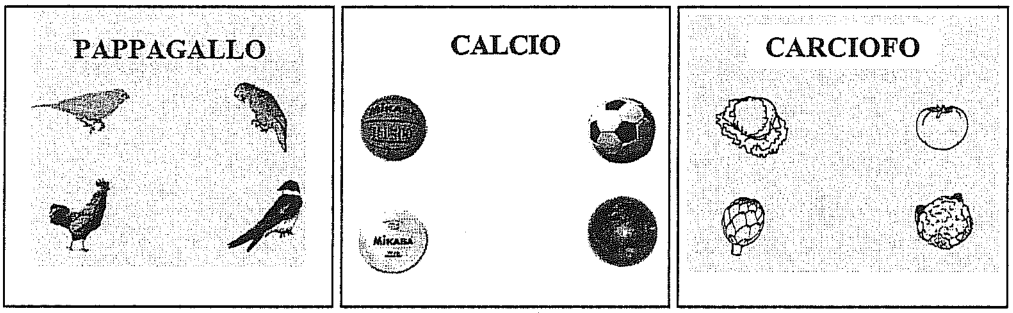

Figure 29. Examples of the Word-to-Picture Matching Task items. From left to right, a coloured picture belonging to the Birds category, a black and white picture belonging to the Balls and a line-drawing picture belonging to the Fruits&Vegetables.

Procedure The pictures appeared on the screen one after the other (through an E-prime© presentation) and lasted until the response release. The patients and the control subjects were required to read the word and choose the corresponding picture. As in the previous experiment, the control subjects and SER were required to give their response pressing a button, while MU was asked to indicate the correct picture on the screen.

Control subjects Both MU and SER were compared with a control group matched for age, sex and education.

4.4.4.3. Results

Living Things

MU was impaired with respect to his control subjects for all the considered sub-categories in both the colour and the black-and-white version of the tasks (see Table 11). SER was at the same level of her control subjects' group for the Fruit-and-Vegetables' category (see Table 11); however, her performance was defective with all the other Living Things sub-classes, even if when the accuracy was quite good, such as in the case of the Animals' sub-category.

	Word-to-Picture Matching Task -Living Things					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Animals (Col)	**0.57**	0.96 (*0.03*)	*-12.97* *p<.0001*	**0.89**	0.99 (*0.02*)	*-4.75* *p<.0001*
Animals (Bw)	**0.61**	0.97 (0.03)	*-10.71* *p<.0001*	**0.89**	0.99 (0.02)	*-4.64* *p<.0001*
Birds (Col)	**0.33**	0.98 (*0.04*)	*-15.50* *p<.0001*	**0.63**	0.97 (*0.03*)	*-9.80* *p<.0001*
Birds (Bw)	**0.38**	0.98 (0.02)	*-25.11* *p<.0001*	**0.63**	0.89 (0.10)	*-2.66* *p<.005*
Small Animals & Insects (Col)	**0.39**	0.97 (*0.06*)	*-10.50* *p<.0001*	**0.72**	0.99 (*0.02*)	*-10.73* *p<.0001*
Small Animals&Insects (Bw)	**0.06**	0.94 (0.05)	*-18.29* *p<.0001*	**0.56**	0.87 (0.12)	*-2.56* *p<.01*
Fruit&Veg (Col)	**0.71**	0.98 (*0.05*)	*-5.50* *p<.0001*	**1.00**	0.96 (*0.02*)	*1.79*
Fruit&Veg (Bw)	**0.62**	0.90 (0.08)	*-3.67* *p<.0001*	**0.90**	0.98 (0.03)	*-2.51* *p<.01*
Plants&Flowers (Col)	**0.28**	0.96 (*0.05*)	*-12.75* *p<.0001*	**0.61**	0.92 (*0.06*)	*-4.91* *p<.0001*
Plants&Flowers (Bw)	**0.17**	0.92 (0.13)	*-5.65* *p<.0001*	**0.72**	0.90 (0.11)	*-1.66* *p<.05*

Table 11. Accuracy proportions for MU, SER and their control subjects in the Word-to-Picture Matching Task (Living Things).

Again, despite SER's performance was good for some sub-classes in the black-and-white condition of the task (i.e. Animals, Fruit&Veg, see Table 11), she was down with respect to her control subjects for all the considered sub-categories.

When the Line-Drawings were used, SER was impaired with respect to her control subjects' group for the Fruit&Veg, while she was at the same level of the control subjects in the case of the Animals (Table 12). MU was clearly impaired in this version of the task with both the Animals and the Fruit&Veg sub-categories.

	Word-to-Picture Matching Task -Living Things: Line Drawing Items					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Animals	**0.68**	--	--	**0.89**	0.93 (0.04)	*-0.82*
Fruit&Veg	**0.48**	--	--	**0.81**	0.96 (0.04)	*-3.82* *p<.0001*

Table 12. Accuracy proportions for MU, SER and their control subjects in the Word-to-Picture Matching Task (Living Things).

Non Living Things

Despite a quite good performance in the case of the Tools and the Textiles[47], MU was down with respect to his control subjects' for all the sub-categories, in both the colour and the black-and-white versions of the task (see the Tables 13).

	Word-to-Picture Matching Task –Non Living Things: Coloured Items					
Sub-category	**MU**	**MU's control subjects: Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects: Average (*sd*)**	***Z-VALUE***
Tools (Col)	**0.88**	0.95 (*0.00*)	*pathological?*	**0.92**	0.93 (*0.04*)	-0.45
Tools (Bw)	**0.88**	1.00 (0.00)	*pathological*	**0.88**	0.98 (0.04)	-2.91 p<.005
Musical Instruments (Col)	**0.59**	1.00 (*0.00*)	*pathological*	**0.64**	0.96 (*0.04*)	-8.61 p<.0001
Musical Instruments (Bw)	**0.55**	1.00 (0.00)	*pathological*	**0.59**	0.98 (0.02)	-15.70 p<.0001
Textiles (Col)	**0.84**	0.99 (*0.03*)	*-5.50 p<.0001*	**0.95**	1 .00 (*0.00*)	*pathological?*
Textiles (Bw)	**0.79**	1.00 (0.00)	*pathological*	**0.84**	0.97 (0.03)	-4.38 p<.0001
Balls (Col)	**0.36**	0.86 (*0.05*)	*-9.60 p<.0001*	**0.50**	0.89 (*0.04*)	-9.62 p<.0001
Balls (Bw)	**0.18**	0.89 (0.05)	*-15.54 p<.0001*	**0.20**	0.87 (0.05)	-13.51 p<.0001

Table 13. Accuracy proportions for MU, SER and their control subjects in the Word-to-Picture Matching Task (Non Living Things).

In the colour version of the task, SER was at the same level of her control subjects with Tools, while she was defective with the other sub-categories. However, she performed very well with Textiles, but still down with respect to the control subjects, which were quite at ceiling (see Table 13). She was down with respect to her control subjects' group for all the sub-categories in the black-and-white version of the task (Table 13).

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[47] It is worth noting that the control subjects were at ceiling in both the coloured and the black-and-white conditions for those sub-categories.

Comparison between the sub-categories: MU

The tasks were grouped as done in the case of the Picture to Word Matching Tasks (see 4.4.3.3), and only the comparisons performed within each group were considered for the discussion (see Figure 30 for a summary of MU and his control subjects' performance).

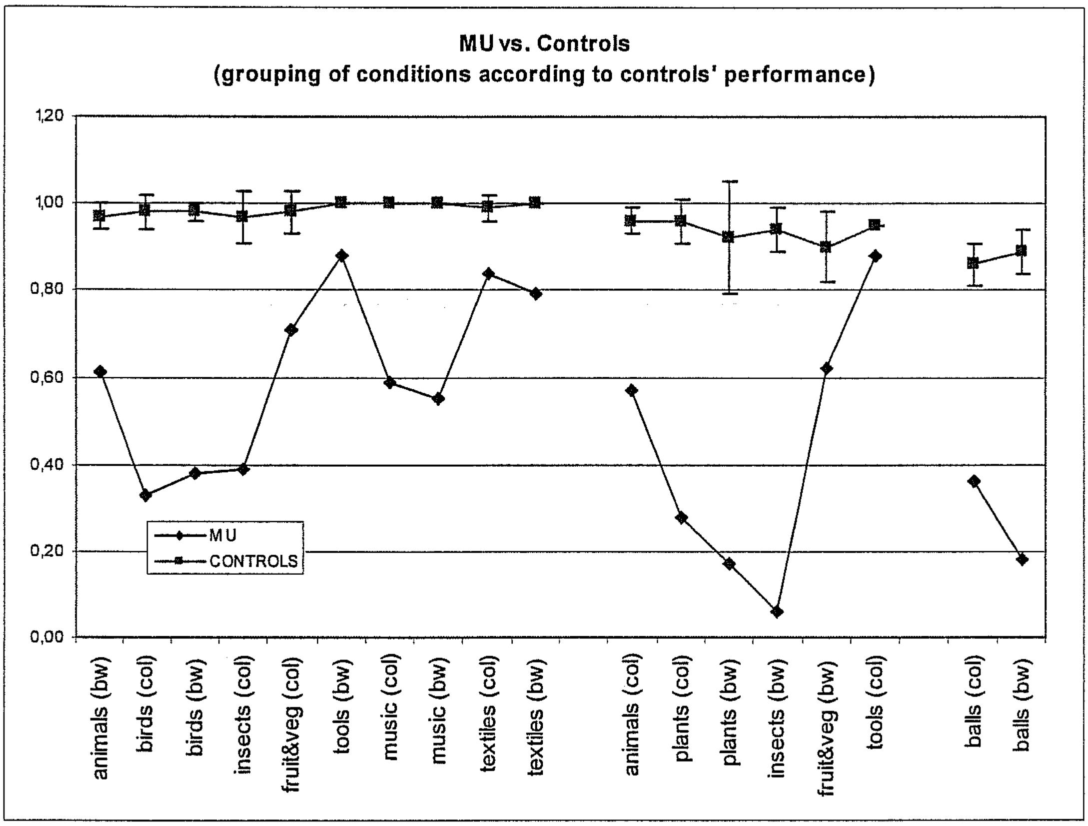

Figure 30. Summary of Word to Picture tasks: conditions are grouped on the base of the controls' performance level (i.e. ceiling, very good and medium performance, represented by the first, the second and the third group of tasks on the x-axis, respectively).

Contrary to what evidenced in the Picture-to-Word Matching task, the Word-to-Picture task seemed to be more sensitive to the sub-category differences.

With respect to the Living Things, MU performed **at the same level with the Fruit&Veg and the Animals**, in black-and-white condition (see Appendix H for details about the stats). The Fruit&Veg were better than the Birds (χ^2=5.71, *df*=1, p<.01) and the Animals were better than the Plants (χ^2=2.31, *df*=1, p=.07, trend) in the colour condition; in the black-and-white condition the Animals were better than the Birds (χ^2=5.51, *df*=1, p<.05) and the Fruit&Veg were better than the Plants (χ^2=3.73, *df*=1, p<.05). Moreover, MU behaved better with the Fruit and Vegetables than the Small Animals with the coloured stimuli (colour condition: χ^2=4.64, *df*=1, p<.05).

No differences emerged between the Tools and the Textiles in the black-and-white condition (χ^2=.40, *df*=1, p=.28, *n.s.*). MU was better with the Tools than with the Musical Instruments (black-and-white: χ^2=5.35, *df*=1, p<.01) and with the Tools than with the Animals and the Plants in the colour condition (χ^2=5.51, *df*=1, p<.01 and χ^2=12.21, *df*=1, p<.001, respectively); he was better with the Tools than with the Animals and the Birds in the black-and-white condition (Tools-Animals: χ^2=4.06, *df*=1, p<.05; Tools-Birds: χ^2=13.54, *df*=1, p<.001). A similar pattern of results emerged for the **Textiles**, which were better than both Musical Instruments (coloured stimuli: χ^2=4.41, *df*=1, p<.05; black-and-white stimuli: χ^2=2.70, *df*=1, p<.05. With respect to the Living Things, the Textiles were better than the Birds and the Small Animals with the coloured stimuli (χ^2=11.38, *df*=1, p<.001 and χ^2=9.79, *df*=1, p<.001, respectively) and the Animals and the Birds with the black-and-white stimuli (χ^2=9.12, *df*=1, p<.01 and χ^2=9.79, *df*=1, p<.001, respectively).

Comparison between the sub-categories: SER

The conditions were grouped with the same logic used for MU (see 4.4.3.3): a synthesis of SER and her control subjects' performance is reported in Figure 31.

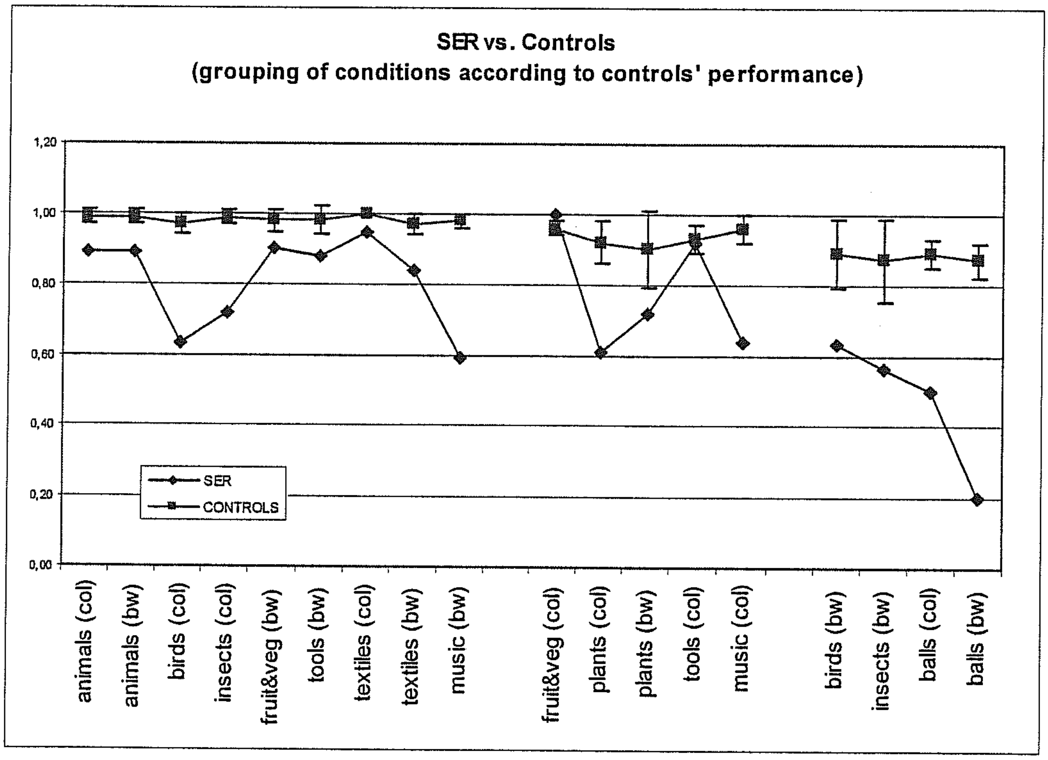

Figure 31. Summary of Word to Picture tasks: conditions are grouped on the base of the controls' performance level (i.e. ceiling, very good and medium performance, represented by the first, the second and the third group of tasks on the x-axis, respectively).

SER was at **the same level with the Fruit and Vegetables and the Animals** in both the colour and the black-and-white conditions. In the colour conditions she showed to perform better with the Fruit&Veg sub-category with respect to the Plants (χ^2=7.85, *df*=1, p<.005). She obtained higher levels of accuracy with Animals than with the Birds (χ^2=4.55, *df*=1, p<.05), the Small Animals (χ^2=3.56, *df*=1, p<.05). The advantage for the Fruit&Veg tended to disappear in the black-and-white condition. No differences emerged between SER's performances with the Birds, the Small Animals and the Plants when compared each other, for both the conditions.

SER was **at the same level when comparing the Fruit&Veg or the Animals with the Tools or the Textiles.** On the contrary she was better with the Fruit and Vegetables than with some Non Living Things sub-categories (colour condition: Fruit&Veg-Music: χ^2=6.44, *df*=1, p<.01; black-and-white condition: Fruit&Veg-Music: χ^2=8.68, *df*=1, p<.005). The Animals were better than the Musical Instruments in the black-and-white condition (χ^2=3.55, *df*=1, p<.05; Animals-Balls: χ^2=12.08, *df*=1, p<.001).

As observed for MU, **the Tools were at the same level of the Textiles** in both the conditions; moreover, the **Tools** were better than the Plants in the colour condition (χ^2=9.07, *df*=1, p<.005). The Tools were better than the Musical Instruments (colour condition: χ^2=7.46, *df*=1, p<.005; black-and-white condition: χ^2=7.42, *df*=1, p<.005). Similarly, the **Textiles** were better than the Birds in the colour condition (χ^2=5.58, *df*=1, p<.05), and the Musical Instruments in the black-and-white condition (χ^2=7.47, *df*=1, p<.01). No differences emerged between the remaining sub-classes, with the exception of the Balls that were worse than some other Living Things' sub-classes in the black-and-white condition (Balls-Birds: χ^2=7.73, *df*=1, p<.005; Balls-Small Animals: χ^2=4.34, *df*=1, p<.05).

4.4.4.4. Summary of the Word-to-Picture Tasks

As observed for the Picture to Word Matching tasks, both the patients were defective for all the conditions considered, with few exceptions. MU was down with respect to his control subjects for both the Living and the Non Living Things, in both the colour and the black and white versions of the task. However, his performance with the Tools was quite good (88% correct for both the conditions) but still defective, since the control subjects performed at ceiling. SER had an impaired performance with the Living Things in all the conditions, with the exception of the coloured Fruit and Vegetables, the line drawings of the Animals and the black and white Tools. As MU, she was quite good with some sub-categories (i.e. Textiles, Tools) but still defective with respect to her control subjects, which performed at ceiling.

Within each patient, the comparison across the sub-categories revealed some specific patterns, which can be summarized as follows:

MU-

(1) the Fruit and Vegetables and the Animals were the best Living Things' subcategories; MU had generally a better performance with these categories than with, the Birds and the Plants (in both the conditions) and the Insects (only colour condition);

(2) the Tools and the Textiles were associated with similar levels of accuracy and they were better than the other artefacts' sub-classes (i.e. the Musical Instruments); moreover, the Textiles were at the same level of the Fruit and Vegetables (at least in the colour condition);

(3) the Balls were a very low sub-category.

SER-

(1) SER performed at the same level with the Fruit and Vegetables and the Animals (at least in the black and white condition); moreover, these two sub-categories were generally associated with higher accuracies than the remaining Living Things classes;

(2) the Tools and the Textiles were associated with similar levels of performance; these two artefacts' classes were better than other Non Living Things;

(3) the Fruit&Veg, the Animals, the Tools and the Textiles were all associated with similar levels of accuracy;

(4) the Tools and the Textiles behaved better than the Musical Instruments and the other Living Things' sub-categories in the colour condition, but this advantage did not emerge in the black and white condition;

(5) as observed for MU, the Balls were associated with very low levels of performance.

4.4.5. Comment to the Matching Tasks (4.4.3 and 4.4.4)

With few exceptions, both the patients showed a generally impaired performance in the Matching tasks, quite irrespectively from the category of belonging of the items (Living vs. Non Living Things) and the kind of material presented (coloured vs. black and white stimuli). These general results confirm the idea that both the patients present with a deep semantic deficit and that their bad performance in the naming tasks (see 4.4.2.3) was not due to anomic problems.

Furthermore, both the patients showed an unimpaired performance for some specific sub-categories. In particular, MU was at the same level of his control subjects for the Tools in the Picture to Word matching task (see 4.4.3.3); in the Word to Picture matching task his performance with the Tools was not at the same level of his control subjects, but still good (88% of correct answer, with the control subjects at ceiling- see 4.4.4.3). The preservation of the Tools' sub-category is in line with the clinical observation of a clear-cut Living-Non Living Things dissociation in MU. SER showed an unimpaired performance only when some specific conditions involving the Living Things were taken into account (i.e. Fruit&Veg, Animals, Small Animals –see 4.4.3.3 and 4.4.4.3). She did not show an advantage for the Non Living Things sub-categories, consistently with the data collected during the clinical assessment.

Despite the general impairment of both the patients with all the categories, the comparison between the sub-classes revealed some important differences.

In both the tasks, MU showed no gross differences across the Living Things' sub-categories, with the exception of the Fruit and Vegetables and the Animals, which performed better than the other sub-classes in the Word to Picture Matching task. Similarly, SR was better with the Fruit&Veg and the Animals than with the other Living Things', mainly in the colour conditions. The disparity between the Fruit&Veg and the Animals and the other sub-categories of the same domain can be easily explained in terms of the frequency and the familiarity of the items.

Both MU and SER showed a better performance with the Tools and the Textiles than with the other Non Living Things sub-categories; conversely, the Musical Instruments and the Balls were associated with low accuracies. The advantage for the Tools and the Textiles over some other sub-categories emerged even when the control subjects performed without differences in accuracy, ruling out a general effect of familiarity or difficulty of the items. Moreover, the Musical Instruments had previously been identified as a peculiar Non Living Things' sub-category, since it is usually impaired (together with the Living Things' items) in the patients showing a Living-Non

Living dissociation. In detail, it has been suggested that the Musical Instruments can't be differentiated on the basis of their function (they are all used to perform music), whereas they have to be discriminated on the basis of very specific visual details (see Capitani et al. 2003 for review and comments). This characteristic of the Musical Instruments renders them very similar to the Living Things' elements (such as, for instance, the fruits and vegetables). We suggest that the patients had a bad performance with the Balls sub-category for a similar reason: the sport-balls share the same function, so that they can be distinguished each other only on the basis of specific visual features.

Furthermore, the sport-balls usually share the same rounded shape, so that they can be identified only on the basis of the colour and the texture/pattern. Thus, we suggest that our patients had difficulty in remembering these elements not only because of the low degree of frequency and familiarity of the items, but also for the specific nature of this kind of stimuli.

In summary, both MU and SER had a general impaired performance in these two tasks. They both showed to be better with some categories than others (i.e. Tools, Textiles, sometimes Animal and Fruit&Vegetables). We interpreted these results as a proof of the presence of semantic deficits in both the patients; moreover, we suggested that the specific advantage for some sub-classes was due to both the frequency/familiarity of items and to the specific characteristics of the categories themselves.

4.5. Experimental investigation on patients: Living and Non Living Things visual tasks –colour and texture-

4.5.1. General aim of the experiments

In order to test the hypothesis that a specific loss for the details of the items can occur, even if the information about the general appearance of the same objects is preserved (aim 2, see 3.1.1), in the following experiments the patients were presented with the *details* (such as the colour and the texture pattern of the surface) of the same objects previously employed. If this hypothesis is true, we would expect a dramatic performance worsening for all the categories, with respect to the performance with the "whole" item presentation.

Therefore, this section will help in understanding whether the surface details can be separately represented, assuming that a dissociation between the global appearance and the detail-representation (in terms of the performance in the Naming and the Matching tasks) can be interpreted as a suggestion in favour of the existence of different levels of representation of these aspects.

4.5.2. Naming tasks: DETAILS

4.5.2.1. Specific aims of the task

This task aimed to investigate the patients' ability to recognize the surface details of the objects without any shape-cue. If the subjects succeed in this task, it would mean they are able to access the semantics about the whole object representation starting from a single feature; the failure in this task, conversely, would suggest the loss of such details-representations or the impossibility to access the whole representation from a single aspect.

4.5.2.2. Methods

Materials A series of photographs depicting the details of specific objects were produced for the Naming task. The pictures represented the details of the items taken from two Living Things sub-categories (i.e. the Animals and the Fruits&Vegetables) and from two Non Living Things sub-classes (i.e. the Textiles and the Balls). These categories were chosen because the colour and texture pattern represent for their elements a very salient feature, often crucial for their recognition.

For each of the four sub-categories' of interest, a picture depicting the surface detail of each item was produced starting from the complete photograph of the object (see Figure 32). As in the previous experiment, coloured and a black and white versions of the stimuli were created. The target-pictures were labelled "Surface Detail Col" (for the coloured version) and "Surface Detail Bw" (for the black and white version). In the case of the Animals' sub-category, we excluded from the task four items, since the corresponding external surface was almost impossible to be recognized without the shape-cue[48].

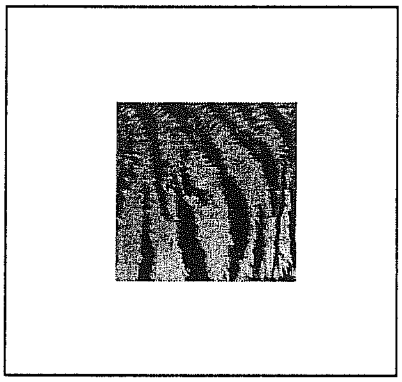

Figure 32. Example of an item (tiger) used in the Naming of Surface Details.

Procedure The pictures were presented to the patients and to the control subjects with the same procedure adopted for the Naming of the entire objects (see 4.4.2.2), with respect to both the presentation and the design. So, for each sub-category, the pictures appeared on the screen in a random order, lasting until the response was given. The patients and the controls were instructed to name the pictures, trying to recognize which object could have such a surface detail. For the black and white version, they were explicitly said that the colour was not present. The accuracy was recorded. More than one response was considered as correct for some items; in particular, in the case of the Textiles a more instruction was given, and the subjects were explained that several objects could share the same surface appearance (i.e. *the table* and *the chair* are both wooden-made): so, they were invited to indicate at least

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[48] The items excluded were: the Deer, the Kangaroo, the Monkey and the Squirrel.

one object that could have that surface pattern, trying to think about the most plausible one[49].

4.5.2.3. Results

MU was very poor in the naming of the Surface Details (see Table 14). It is worth noting that the task was highly difficult for control subjects as well: MU was at the control subjects' level only for the more difficult condition (i.e. the Textiles, black-and-white version), where they were very low in accuracy (i.e. 22% correct).

Similarly, SER was impaired with respect to her control subjects in both the colour and the black-and-white conditions, with the exception of the Textiles category (see Table 14).

	Naming: Surface Details					
Sub-category	**MU**	**MU's control subject Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects average (*sd*)**	***Z-VALUE***
Animals (Col)	0.04	0.40 (*0.09*)	*-4.10* *p<.0001*	**0.08**	0.48 (*0.10*)	*-4.02* *p<.0001*
Animals (Bw)	0.04	0.49 (*0.08*)	*-5.68* *p<.0001*	**0.13**	0.38 (*0.06*)	*-4.17* *p<.0001*
Fruit&Veg (Col)	0.29	0.79 (*0.12*)	*-4.06* *p<.0001*	**0.52**	0.88 (*0.03*)	*-11.97* *p<.0001*
Fruit&Veg (Bw)	0.14	0.53 (*0.14*)	*-2.67* *p<.0001*	**0.57**	0.72 (*0.05*)	*-2.92* *p<.005*
Textiles (Col)	0.21	0.43 (*0.14*)	*-1.62* *p<.05*	**0.32**	0.36 (*0.14*)	*-0.31*
Textiles (Bw)	0.16	0.22 (*0.14*)	*-0.82*	**0.26**	0.27 (*0.08*)	*-0.13*

Table 14. Accuracy proportions for MU, SER and their control subjects in the Details' Naming Task.

However, it is worth noting that, despite the control subjects were quite at the same level of accuracy with the Animals' and the Textiles' sub-categories (black-and-white stimuli), SER was impaired only for the former category (see Table 14), thus suggesting a specific difficulty with the Living Things' domain[50].

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[49] The Textiles' items for which more than a response was accepted were: the *bathrobe* → *bathrobe, towel*; the *door-mat* → *door-mat, carpet*; the *down jacket* → *down jacket, jacket, eider-down*.

[50] One could object that task was too much difficult to perform, since control subjects performed quite badly as well, for the majority of sub-classes considered. However, patients' performance was always very bad, even when control

4.5.2.4. Comment to the Naming of Details

In general, MU and SER were deeply impaired in all these naming tasks, despite the control subjects had a low performance as well for most of the sub-categories.

The patients were at the control subjects' level only with the lowest sub-categories (i.e. the Textiles); moreover, both the patients (but MU especially) were impaired with the Fruit and Vegetables' class, despite a better performance of the control subjects with this material (at least with the coloured condition), showing a generalized problem with the details' recognition, not completely explainable by the difficulty of the task.

4.5.3. Picture to Word Matching Tasks: DETAILS

4.5.3.1. Specific aims of the task

The task aimed to better investigate the recognition abilities of both the patients with the detail-items, excluding the effects of any anomic problem (as just argued in 4.4.3.1).

4.5.3.2. Methods

Materials The items from the Naming were here employed in a matching to sample task, in which each item comprised the target-picture and four words, including the target-word, in the same logic of the Picture to Word for entire items (see 4.4.3.2). Again, the distracters corresponded to 3 items in a different degree of similarity with target; the similarity was evaluated on the basis of both the semantic and the visual correspondence to the detail (and not the entire-object concept). Some examples of the alternatives are shown in Figure 33.

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subjects succeed the task (i.e. Fruits & Vegetables condition), suggesting that difficulty can play only a limited role in explaining the pattern of results.

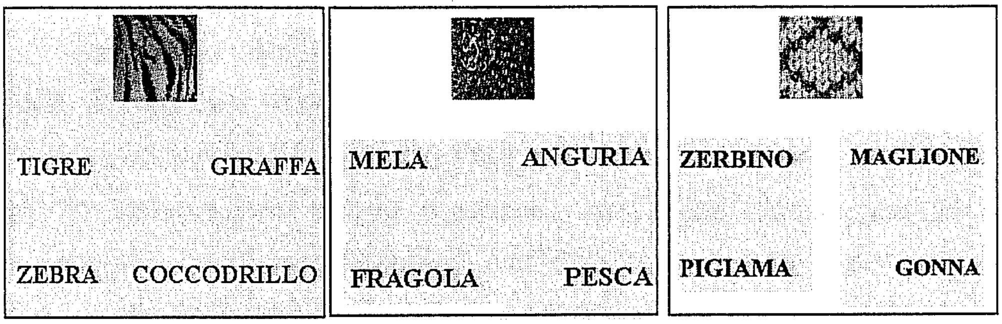

Figure 33. Examples of the Picture-to-Word Matching Task items. From left to right, An Animal-item (the Tiger), a Fruits&Vegetables-item (the Strawberry) and a Textiles-item (the Sweater).

As done for the entire items, a colour and a black and white version of all the stimuli were created, resulting in two separate conditions for each target-type.

Procedure The procedure was identical to the previous Picture to Word Matching task (see 4.4.3.2 for details). Again, SER and the control subjects were required to press one of four alternative buttons on the keyboard in order to give their answer, while MU was asked to read the word corresponding to the target-picture and he was helped by experimenter to press the buttons.

Control subjects Both MU and SER were compared with a group of control subjects, matched for age, sex and education.

4.5.3.3. Results

MU and SER were down with respect to their control subjects with all the considered categories for both the coloured and the black-and-white stimuli (see Table 15). In detail, MU showed no gross differences across the sub-categories, nor he showed a colour-deprivation effect. SER showed no gross differences across the sub-classes, with the only exception of a better performance with the Animals (in the black-and-white condition), for which her performance was close to normality (z=-1.71, p<.05).

	Picture-to-Word Matching Task: Surface Details					
Sub-category	**MU**	**MU's control subject Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects average (*sd*)**	***Z-VALUE***
Animals (Col)	**0.33**	0.94 (*0.04*)	*-14.20* *p<.0001*	**0.67**	0.92 (*0.07*)	*-3.79* *p<.0001*
Animals (Bw)	**0.29**	0.93 (*0.05*)	*-12.12* *p<.0001*	**0.58**	0.81 (*0.06*)	*-3.54* *p<.0005*
Fruit&Veg (Col)	**0.38**	0.94 (*0.09*)	*-6.27* *p<.0001*	**0.81**	0.93 (*0.07*)	*-1.71* *p<.05*
Fruit&Veg (Bw)	**0.38**	0.80 (*0.06*)	*-6.95* *p<.0001*	**0.67**	0.84 (*0.07*)	*-2.44* *p<.01*
Textiles (Col)	**0.37**	0.95 (*0.04*)	*-13.47* *p<.0001*	**0.63**	0.88 (*0.04*)	*-5.74* *p<.0001*
Textiles (Bw)	**0.32**	0.71 (*0.14*)	*-2.83* *p<.0001*	**0.53**	0.79 (*0.11*)	*-2.50* *p<.01*

Table 15. Accuracy proportions for MU, SER and their control subjects in the Details' Picture-to-Word Matching Task.

4.5.4. Word to Picture Matching Tasks: DETAILS

4.5.4.1. Specific aims of the task

A Word to Picture Matching task was presented, as done for the entire-items (see 4.4.4). As previously discussed, the main aim of this task was to investigate the patients' capacity to access the object visual representation from the words. In this case, the word allows the structural description representation for the "complete" object; a second step-representation is required in order to succeed the task, since the subjects have to completely represent the visual aspects about the target before choosing the corresponding detail from the given alternatives.

4.5.4.2. Methods

Materials The items used in the Naming task were here employed in a matching to sample task, in which each item comprised a target-word and four pictures, depicting the Surface Detail corresponding to the target and three surface details taken from other objects, in the same logic of the Word to Picture -entire items (see 4.4.4.2). Again, the distracters corresponded to three items in a different degree of similarity with the target; the similarity was evaluated on the basis of both the semantic and the visual correspondence to the detail (and not the entire-object concept). Examples of the alternatives are shown in Figure 34.

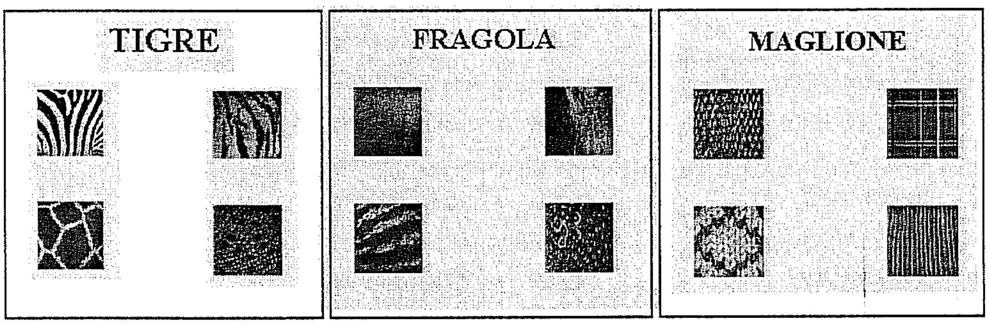

Figure 34. Examples of Word-to-Picture Matching Task items. From left to right, an Animals-item (the Tiger), a Fruits&Vegetables-item (the Strawberry) and a Textiles-item (the Sweater).

Procedure The procedure was similar to the previous experiments. The subjects were required to match the target-word with the corresponding detail pressing one of the four indicated buttons on the keyboard.

4.5.4.3. Results

Both MU and SER were impaired in this task (see Table 16), irrespectively from the sub-category and from the condition (coloured vs. black-and-white stimuli).

	Word-to-Picture Matching Task: Surface Details					
Sub-category	**MU**	**MU's control subject Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects average (*sd*)**	***Z-VALUE***
Animals (Col)	**0.45**	0.89 (*0.09*)	*-4.71* *p<.0001*	**0.50**	0.89 (*0.08*)	*-5,01* *p<.0001*
Animals (Bw)	**0.25**	0.88 (*0.09*)	*-6.94* *p<.0001*	**0.54**	0.84 (*0.10*)	*-2,98* *p<.002*
Fruit&Veg (Col)	**0.43**	0.94 (*0.02*)	*-21.50* *p<.0001*	**0.81**	0.94 (*0.04*)	*-3,27* *p<.001*
Fruit&Veg (Bw)	**0.05**	0.85 (*0.09*)	*-8.85* *p<.0001*	**0.71**	0.92 (*.03*)	*-8,03* *p<.0001*
Textiles (Col)	**0.42**	0.82 (*0.13*)	*-3.15* *p<.0001*	**0.62**	1.00 (*0.00*)	*pathological*
Textiles (Bw)	**0.42**	0.83 (*0.11*)	*-3.76* *p<.0001*	**0.57**	0.89 (*0.06*)	*-5,02* *p<.0001*

Table 16. Accuracy proportions for MU, SER and their control subjects in the Details' Word-to-Picture Matching Task.

4.5.4.4. Comment to the Picture Matching tasks- Details

Both the patients showed an impaired performance in these tasks, irrespectively from the kind of stimuli (colour vs. black and white), the direction of the matching (i.e. Picture to Word vs. Word to Picture) and, crucially, the category of belonging of the items. These results confirm the idea that both the patients have a generalized difficulty in retrieving and managing the visual information about the objects; moreover, the persistence of the impairment in a facilitated task suggests that the problem is not ascribable to mere access difficulties, as could be proposed in the case of the Naming Task.

4.5.4.5. Comparisons between the conditions for the three crucial categories

- **Fruits and Vegetables**

Item vs. Surface Detail MU was better with the *Items*[51] than the *Surface Details* in the Word to Picture-colour version ($\chi^2=2.75$, *df=1*; p=.048), while no differences emerged in the Picture to Word -colour version ($\chi^2=0.69$, *df=1*; p=.35, *n.s.*). Moreover, in the black and white versions of the tasks he was better with the *Items* than the *Surface Details* in both the PW ($\chi^2=0.11$, *df=1*; p=.057, *trend*) and the WP ($\chi^2=9.15$, *df=1*; p<.005). SER showed no differences between the Items and the Surface Details in terms of accuracy in any of the tasks[52].

Colour vs. Black-and-White conditions No differences emerged contrasting the colour vs. the black-and-white versions for the *Items* in the Picture to Word ($\chi^2=0.02$, *df=1*; p=.45, *n.s.*), the *Items* in the Word to Picture ($\chi^2=0.50$, *df=1*; p=.24, *n.s.*) nor the *Surface Details* in the Picture to Word ($\chi^2=1.08$, *df=1*; p=.15, *n.s.*); on the contrary, MU performed better with the coloured Surface Details in the Word to Picture task ($\chi^2=5.66$, *df=1*; p<.01).

Again, SER showed no differences between the colour and the black-and-white versions of the tasks[53].

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[51] Data relative to Animals, Fruit&Veg and Textiles in the Item-conditions is reported in 4.4.3.3.

[52] *Items* vs. *Surface Details*: coloured version of the PW ($\chi^2=0.57$, *df=1*; p=.25, *n.s.*); coloured version of the WP ($\chi^2=2.12$, *df=1*; p=.12, *n.s.*); black-and-white version of the PW ($\chi^2=0.18$, *df=1*; p=.37, *n.s.*); black and white version of the WP ($\chi^2=1.25$, *df=1*; p=.33, *n.s.*).

[53] *Coloured* vs. *Black-and-White conditions*: *Items*-PW ($\chi^2=0.06$ *df=1*; p=.41, *n.s.*); *Items*-WP ($\chi^2=0.92$, *df=1*; p=.26, *n.s.*); *Surface Details*-PW ($\chi^2=0.74$, *df=1*; p=.23, *n.s.*); *Surface Details*-WP ($\chi^2=0.17$, *df=1*; p=.36, *n.s.*).

- **Animals**

Item vs. Surface Detail MU was better with the *Items*[54] than the *Surface Details* in the Picture to Word colour version (χ^2=3.57, *df=1*; p<.05), while no differences emerged in the Word to Picture colour version (χ^2=0.27, *df=1*; p=.30, *n.s.*). In the black-and-white versions of the tasks he was better with the *Items* than the *Surface Details* in both the Picture to Word (χ^2=4.85, *df=1*; p<.05) and the Word to Picture (χ^2=4.18, *df=1*; p<.05).

SER was better with the Items than the Surface Details in the colour version of both the Picture to Word (χ^2=9.17, *df=1*; p<.05), and the Word to Picture (χ^2=6.32, *df=1*; p<.05); on the contrary, she failed to show any difference in the black-and-white conditions[55].

Colour vs. Black-and-White conditions For both MU and SER, no differences emerged between the colour and the black-and-white versions of the Animals tasks for any condition[56].

- **Textiles**

Item vs. Surface Detail With the Textiles, MU was better with the *Items*[57] than the *Surface Details* in both the Picture to Word colour version (χ^2=3.93, *df=1*; p<.05) and the Word to Picture colour version (χ^2=4.40, *df=1*; p<.05).

In the black-and-white versions of the tasks he was better with the *Items* than the *Surface Details* in the Word to Picture (χ^2=5.44, *df=1*; p<.01), while no differences emerged between the conditions in the Picture to Word (χ^2=0.20, *df=1*; p=.33, *n.s.).*

SER was better with the Items than the Surface Details in all the Textiles' conditions, with the exception of the Picture to Word-colour version (χ^2=1.58, *df=1*; p=.13, *n.s.*): in detail, she was better with the Items in Word to Picture colour version

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[54] Data relative to Animals, Fruit&Veg and Textiles in the Item-conditions is reported in 4.4.3.3.

[55] *Items* vs. *Surface Details*: black-and-white version of the PW (χ^2=0.81, *df=1*; p=.20, *n.s.*); black and white version of the WP (χ^2=0.01, *df=1*; p=.45, *n.s.*).

[56] *Coloured* vs. *Black-and-White conditions*- MU: *Items*-PW (χ^2=1.00 *df=1*; p=.50, *n.s.*); *Items*-WP (χ^2=0.01, *df=1*; p=.45, *n.s.*); *Surface Details*-PW (χ^2=0.06, *df=1*; p=.41, *n.s.*); *Surface Details*-WP (χ^2=1.78, *df=1*; p=.09, *n.s.*). SER: *Items*-PW (χ^2=0.67 *df=1*; p=.23, *n.s.*); *Items*-WP (χ^2=0.75, *df=1*; p=.21, *n.s.*); *Surface Details*-PW (χ^2=0.01, *df=1*; p=.45, *n.s.*); *Surface Details*-WP (χ^2=1.74, *df=1*; p=.11, *n.s.*).

[57] Data relative to Animals, Fruit&Veg and Textiles in the Item-conditions is reported in 4.4.3.3.

(χ^2=4.50, *df=1*; p<.05) and in both the Picture to Word black-and-white (χ^2=2.90, *df=1*; p=.06, trend) and the Word to Picture black-and-white (χ^2=0.50, *df=1*; p<.05).

Colour vs. Black-and-White conditions Again, both MU and SER showed no effects of colour in any condition[58].

4.5.4.6. Comment of the crucial comparisons

In summary, MU was better with the Items[59] for quite all the conditions than the Surface Details, irrespectively from the category (even if there were some exceptions for each category).

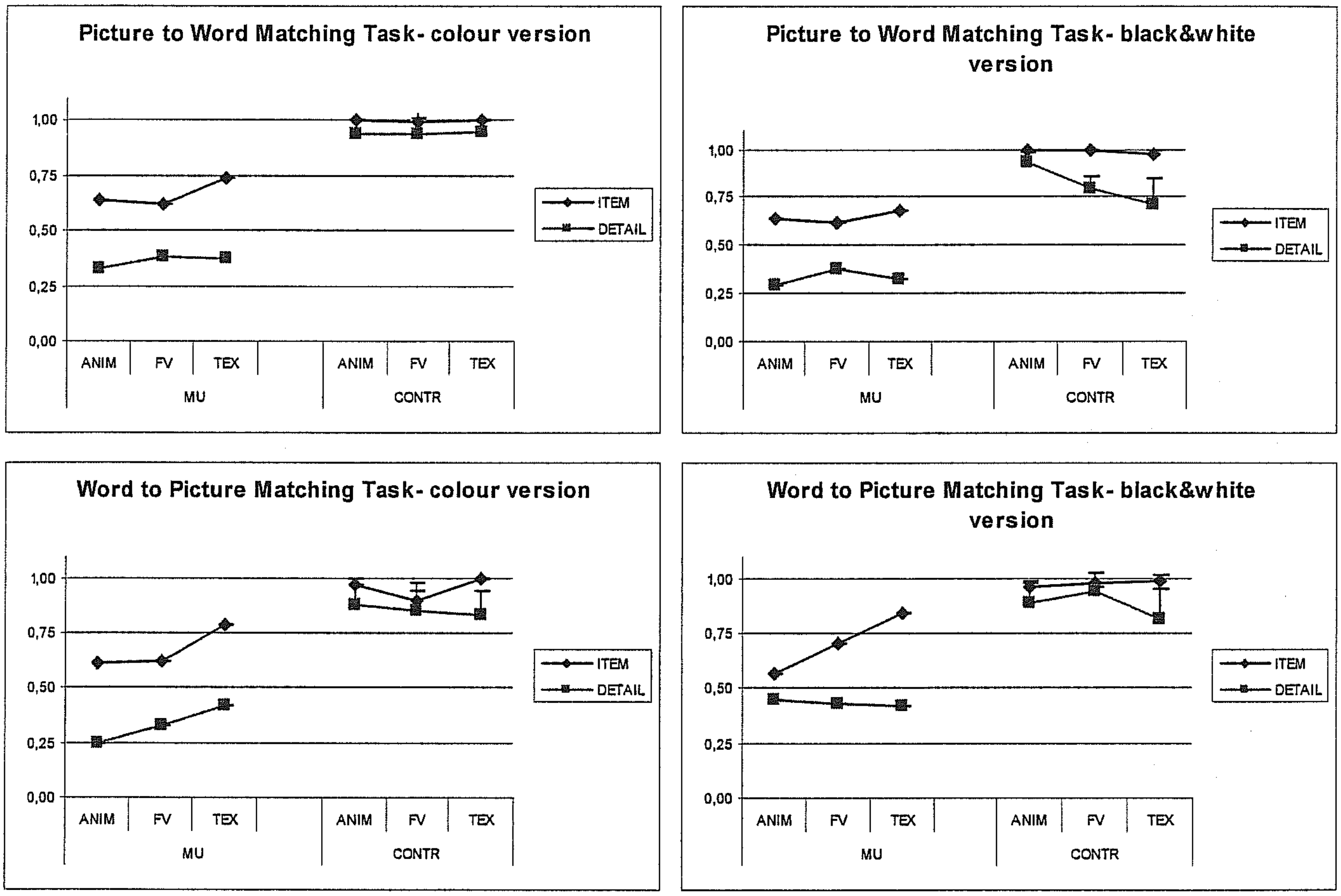

Figure 35. Accuracy proportions of MU and his control subjects in the Matching Tasks- relevant categories. The bars represent one standard deviation. ANIM = Animals; FV = Fruit and Vegetables; TEX = Textiles; CONTR = control subjects.

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[58] *Coloured* vs. *Black-and-White conditions-* MU: *Items*-PW (χ^2=0.04, *df=1*; p=.42, *n.s.*); *Items*-WP (χ^2=0.67, *df=1*; p=.21, *n.s.*); *Surface Details*-PW (χ^2=0.61, *df=1*; p=.22, *n.s.*); *Surface Details*-WP (χ^2=0.73, *df=1*; p=.20, *n.s.*). SER: *Items*-PW (χ^2=0.04 *df=1*; p=.42, *n.s.*); *Items*-WP (χ^2=0.61, *df=1*; p=.24, *n.s.*); *Surface Details*-PW (χ^2=0.58, *df=1*; p=.26, *n.s.*); *Surface Details*-WP (χ^2=0.83, *df=1*; p=.18, *n.s.*).

[59] See Table 8 and 10 for Picture to Word-Item, Living and Non Living Things, respectively; see Table 11 and 13, for Word to Picture, Living and Non Living Things, respectively.

On the contrary, SER showed a lesser degree of disparity between the two conditions, being at the same level with the Items and the Details for all the tasks involving the Fruit and Vegetables (see Figures 35 and 36 for a direct comparison between the control subjects vs. MU and SER, respectively). The pattern of performance was more clear and consistent across the conditions when comparing the colour and the black-and-white material: both the patients showed no advantage for the colour presence. This result suggests that the colour was not critical in order to recognize the details used in the study.

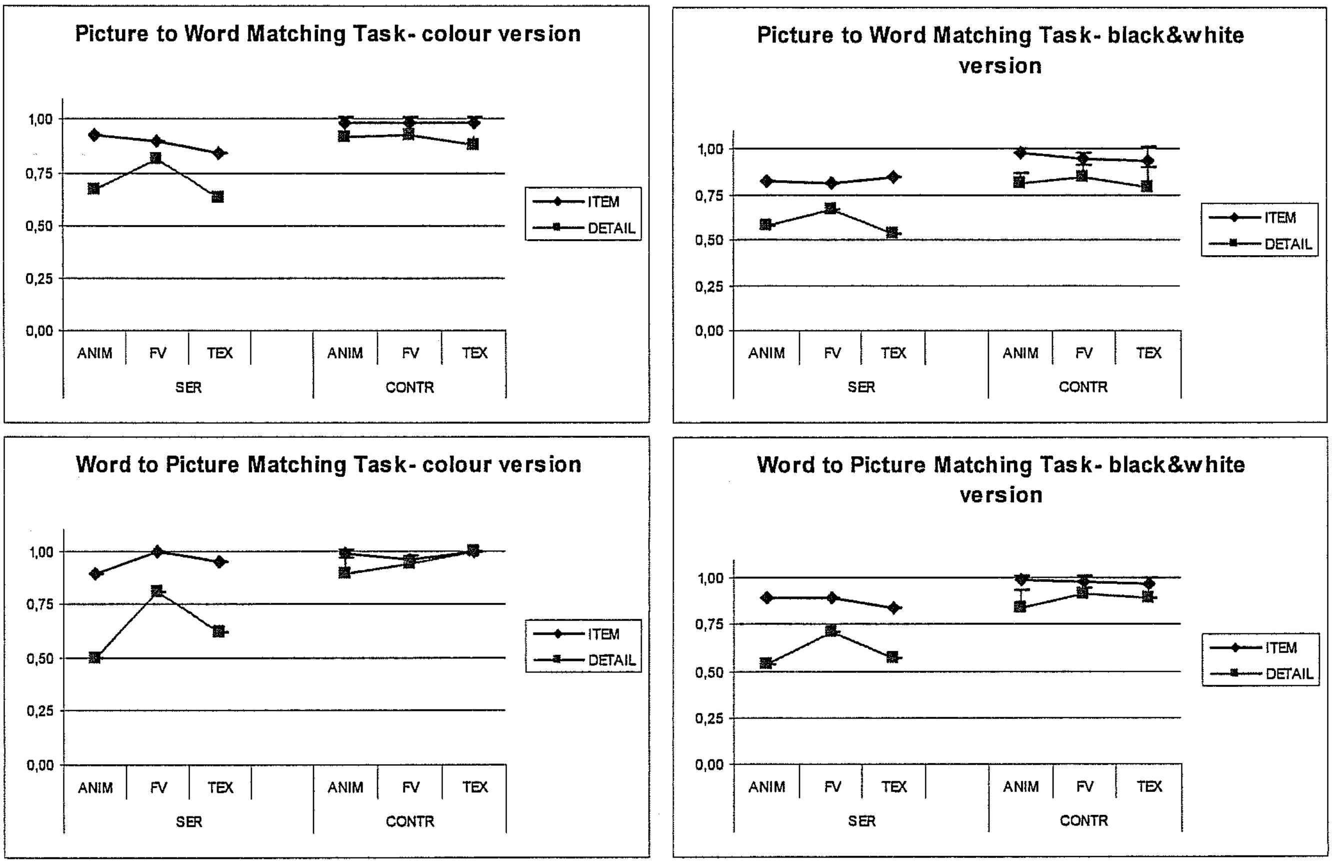

Figure 36. Accuracy proportions of SER and her control subjects in the Matching Tasks- relevant categories. The bars represent one standard deviation. ANIM = Animals; FV = Fruit and Vegetables; TEX = Textiles; CONTR = control subjects.

As a further point, MU and SER behaved quite in the same fashion for the Animals' and the Textiles' categories, whereas they had very different results in the case of the Fruit and Vegetables, for which, contrary to MU, SER did not show an advantage for the Items over the Details. This result is quite interesting, since it confirms the idea, just developed in the literature (Warrington & McCarthy, 1987), that some classes of objects can behave in a specific way, depending on the importance of the visual aspects in their identification.

4.5.5. Picture-Picture Matching Task

4.5.5.1. Specific aims of the task

In this section we present some tasks that allow to investigate the direct relation between the object-shape and the object-details without requiring a verbal answer (word retrieval or recognition).

Both the patients showed a bad performance with the Details as a general trend; moreover, they were generally worse with the Details than with the correspondent entire objects (Items), even if with some exceptions. We interpreted these results suggesting that the specific visual surface details can be represented independently from the shape, thus being susceptible to a selective loss (despite the preservation of the shape-representation). With these visual tasks we aim to exclude that the problems observed in managing the surface details would be due to imagery problems, which would unable the patients to retrieve the shape-representation from memory. Thus, if the patients would be better in solving the visual matching tasks (shape-to-detail) than the verbal ones (word-to-details), we would consider the imagery-deficit hypothesis more plausible.

We assume that giving the shape would facilitate the solution of the task only if the identification of the surface details is sustained by the shape-representation (as suggested by Walker & Cuthbert, 2003, see 2.2.6): i.e. if you need to activate the Structural Description of one object in order to access the correspondent surface details.

Furthermore, Warrington & Crutch (2004) described a visual-visual matching of structurally dissimilar objects (see 4.2.2). In detail, their patient, who presented with a problem in access to the verbal semantics, was required to associate the pictures of a diverse exemplar of the target object, choosing it between distracters similar for name or function. The authors found a clear cut dissociation between the performance of the patient in this task and to a verbal-visual matching task involving the same items, and they claimed that this could be a further evidence in favour of the existence of a visual semantic system which is separate from a verbal one. With respect to our experiment, the important assumption made by Warrington & Crutch (2004) is that a visual-visual matching task like the one they used requires a semantic access in order to be succeeded.

Our task is similar to the one described by Warrington & Crutch (2004), with the exception that the target object has to be associated with a fine detail of the object itself (and not with a diverse exemplar representing the same object). Thus, we think that it is reasonably to assume that the task we are going to describe is accessing semantics as well.

Thus, as previously pointed out, a better performance in this task than in the verbal ones would suggest a possible imagery deficit in the patients; on the contrary, a similar performance would be interpreted as the confirmation of the semantic access in both kinds of tasks. Finally, a worse performance would let think about a specific (not semantic) problem in managing visual material.

4.5.5.2. Methods

Materials The entire items and the details employed in the previous experiments were used here in two tasks, where the Line-Drawings of the entire objects had to be associated with their corresponding Surface Details (see Figure 37 for examples).

Thus, the two tasks mimicked the previously presented Picture-to-Word and Word-to-Picture Matching Tasks involving the details (see 4.5.3.2 and 4.5.4.2, Figure 26 and 29, respectively), with the difference that the words presented (as the alternatives or the target, respectively) had been substituted with pictures (see Figure 37).

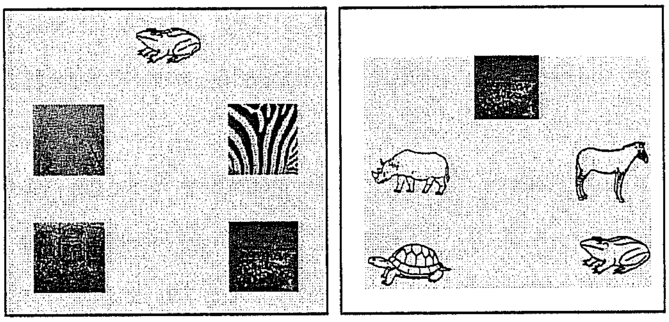

Figure 37. On the left, an example of the Picture-Picture Matching Task created from the Word-to-Picture (Surface Details): the word "frog" was substituted with the line-drawing of a frog. On the right, an example of the Picture-Picture Matching Task created from the Picture-to-Word (Surface Details): the alternative words (rhinoceros, zebra, turtle, frog) were substituted with the corresponding line-drawings.

Procedure The same procedure employed in the previous experiments was used here (see 4.5.3.2 and 4.5.4.2), with the exception of the instructions. In the first version the subjects were told that a picture would appear on the screen together with four possible details, and they were required to match the shape with the correct detail.

In the second version of the task the subjects were required to look at one detail and choose the corresponding entire-shape between the four alternatives. SER and their control subjects gave their response by pressing the button-keys, while MU was asked to indicate the correct alternative on the computer screen with the finger.

4.5.5.3. Results

MU and SER were impaired in these tasks for both the categories (see Table 17). Despite she was defective in all the conditions, SER showed a slightly better performance with the Fruit and Vegetables' sub-class, being her accuracy close to normality in the Surface Detail-to-Item Matching task ($z=-1.71$, $p<.05$). On the contrary, she was dramatically impaired with the Animals, where her performance was at chance in the Item-to-Surface Detail condition (22% correct answer).

		Picture-to-Picture Matching					
Sub-category	**Test**	**MU**	**MU's control subjects Average (*sd*)**	***Z-VALUE***	**SER**	**SER's control subjects Average (*sd*)**	***Z-VALUE***
Animals	**Item to Surface Detail**	0.42	0.91 (0.06)	*-7,83* *p<.0001*	0.22	0.83 (*0.03*)	*-20.91* *p<.0001*
	Surface Detail to Item	0.46	0.93 (0.07)	*-6,59* *p<.0001*	0.54	0.83 (*0.15*)	*-1.92* *p<.05*
Fruit&veg	**Item to Surface Detail**	0.48	0.86 (*0.04*)	*-9,80* *p<.0001*	0.76	0.91 (*0.04*)	*-3.82* *p<.0001*
	Surface Detail to Item	0.20	0.89 (0.10)	*-3,76* *p<.0002*	0.76	0,89 (*0.07*)	*-1.71* *p<.05*

Table 17. Accuracy proportions for MU, SER and their control subjects in the Picture-to-Picture Task.

4.5.5.4. Comparison between the verbal and the visual tasks

The Picture-Picture Matching tasks were compared with the corresponding verbal condition. In detail, the Item to Surface Detail was compared with the Word to Picture-Details (see 4.5.4), and the Surface Detail to Item with the Picture to Word-Details (4.5.3), respectively. MU showed no differences when comparing the Item-to-Surface Detail vs. the Word-to-Picture-Details tasks, ($\chi^2=.14$, *df*=1, p=.35, *n.s.*) and the Surface Detail-to-Item vs. the Picture-to-Word-Detail tasks ($\chi^2=.03$, *df*=1, p=.86, *n.s.*). Similarly, SER was at the same level with the Item-to-Surface Detail and the

Word-to-Picture-Detail tasks (χ^2=0, *df*=1, p=.50, *n.s.*) and with the Surface Detail-to-Item and the Picture to Word-Detail (χ^2=.48, *df*=1, p=.24, *n.s.*).

4.5.5.5. Comment to the Picture-Picture Matching Tasks

In summary, both MU and SER failed to show a difference in terms of accuracy between the verbal and the visual conditions. This means that, when they were required to recognize and managing the surface visual aspects of the objects, it was quite the same if the shape dimension was given or not. These results exclude the possibility that the patients failed in the previous tasks because of an imagery difficulty.

On the basis of these results, it seems plausible to sustain the idea that –at least for MU and SER- the visual surface aspects of objects are not represented in a strong association with the Structural Description, contrary to what claimed by Walker & Hinkley (2003).

Moreover, following Warrington & Crutch (2004), we would interpret the lack of difference between the visual and the verbal matching tasks as a further evidence in favour of the necessary access to the semantic system.

4.6. Discussion

4.6.1. Summary of the results and comments

Our patients were presented with objects taken from different sub-categories of the two main domains of living and non living things. The stimuli consisted alternatively in whole objects or details of the surface of the same elements; moreover, the amount of information given in the stimuli was varied across the conditions, with particular respect to the colour dimension.

Both patients showed a **very impaired performance in Naming Tasks with all the sub-category** considered in the study (see 4.4.2), quite irrespectively from the domain of belonging of the items (Living vs. Non Living Things) and the kind of material used (i.e. coloured pictures-black and white pictures-line drawings). These findings were confirmed with the presentation of two matching tasks (4.4.3 and 4.4.4), in which the patients were required to associate the pictures with the corresponding word.

This quite generalized impairment was interpreted as a strong **semantic deficit** in the patients; moreover, the consistency of the deficit across the two kinds of tasks (naming vs. matching tasks) excluded, in our opinion, the possibility that the problem was due to anomic or access difficulties.

Furthermore, basing on the observation that the colour determined no facilitation on the tasks, it appears difficult to sustain the hypothesis that the visual properties are crucial in recognition, at least for the considered classes of objects.

However, whereas no gross differences emerged between the sub-categories in the Naming task (see 4.4.2.3), both patients showed some peculiarities of performance in the matching tasks (see 4.4.5). In detail, we found that **MU behaved clearly better with the Tools' sub-category** over the other artefacts and the Living Things' class. **Both MU and SER had a better performance with the Textiles than with the Balls and the Musical Instruments**. The similar behaviour of musical instruments and the living beings in patients has been explained basing on the assumption that these categories are strongly defined by their perceptual properties, whereas their functional attributes are not sufficient in order to distinguish between the exemplars. We found that the Balls' sub-category behaves similarly, since the patients had a very bad performance with this class in both the naming and the association tasks. Despite the possible contribution of frequency and familiarity effects in determining this pattern of performance, we suggest that the recognition of the Balls is highly depending on the visual characteristics of the items, since the function and the other properties (including the shape) are shared across the exemplars of the category, similarly to what happens in the case of the Fruit and Vegetables and, as just commented, the Musical Instruments.

When considering the tasks involving the details, which were restricted to the Animals, the Fruit&Veg and the Textiles, we found that both MU and SER were clearly impaired with all the conditions. Again, no differences between the coloured and the black and white stimuli were found; moreover, no strong disparities among the categories emerged.

The graphs presented in the Figures 35 and 36 clearly show the pattern of performance for the two patients, compared with their control subjects. What appeared clear from the direct comparison between each condition was that both patient was better with the item than with the corresponding detail, irrespectively from the colour presence and the category of belonging of the items.

These findings have two main consequences: **(1) the patients have a specific difficulty with the details of the objects; (2) this difficulty is not confined to the living things, but it is extended to the categories for which a good performance was observed in the item-conditions** (even if it was defective with respect to the normal subjects).

One objection to these tentative conclusions is that the details-conditions are more difficult. This is clearly true, in particular for patients with no perfect cognitive profile (as the two studied here). However, as we have previously commented (see 4.5.4.4), the lack of a strong improvement in the facilitated conditions and, in any case, the persistence of the effects in the matching tasks (which are supposed to be facilitated with respect to the naming) seems to exclude the possibility that the effects are merely due to the different degree of difficulty.

Moreover, the existence of some exceptions to the general trend -see paragraph 4.5.4.5 for examples- suggests that the difficulty of task per se is not sufficient in order to explain the specific differences between some Item and Detail conditions.

With respect to the second point, we considered, for instance, that both the patients had a quite good performance (well above the chance level) with the Texture category in both the Matching tasks involving the Items (see 4.4.3.3 and 4.4.4.3), whereas their accuracy for the same category was worse in the same conditions when involving the Details (4.5.3.3 and 4.5.4.3), and even almost at chance for MU (see Table 15 and 16, for the Picture to Word Details and Word to Picture Details, respectively). This result is quite interesting, since it suggests that the difficulty of patients in retrieving visual properties of objects is not restricted to the living things classes, but can be ascribed to the artefacts category as well. We will further comment about this in the next paragraph.

4.6.2. Fulfilling the aims

Despite the results of the neuropsychological investigation are not strong, in that we can't completely exclude familiarity, frequency and difficulty effects, we tried to use the qualitative observation of the patients' performance in all the presented tasks in order to test the three main hypothesis of the study.

(1) We firstly would like to test the hypothesis of the possible role of visual features in object recognition and representation. When we compared the different conditions, which involved diverse amounts of visual information (i.e. line drawings - coloured stimuli - black and white stimuli), we found that the patients had similar levels of performance: this finding does not support the hypothesis that the surface visual properties contribute in the recognition of objects (at least not for the categories considered in the study). However, it is worth emphasizing that patient' performance was defective in the large part of the tasks, even when the complete visual information was given (i.e. coloured items): this general and basic difficulty of patients in managing the material of the study at the simplest levels prevents us in making strong inferences about the role of visual information on the recognition process. What we can just say is that the visual information is not helping our patients in retrieving the concepts they are difficult with.

However, the lack of difference between the conditions involving colour+texture (i.e. coloured items) and the conditions with texture alone (i.e. black and white items) can suggest a not strong role of the colour dimension in the object recognition.

Actually, whereas no gross differences emerged between the conditions in which the stimuli were presented with colour and texture (bound together, i.e. coloured items) and with the texture dimension only (i.e. black and white stimuli), a decrease in performance is evident when both the dimensions were hidden (i.e. line Drawings).

This was true at least for MU, who had a worse performance with the line drawings of the Animals and, more evidently, of the Fruit&Veg category (in the

Naming -4.4.2.3, Table 6-, in the Picture to Word -4.4.3.3, Table 9- and in the Word to Picture -4.4.4.3, Table 12).

Unfortunately we did not present the line drawing stimuli for the other sub-categories, so that we can't exclude that this effect would be extended to other living and non living things' classes. If the effect would extend to other categories, this would mean that the colour and the texture in particular play a general facilitation on the object recognition. On the other hand, if the effect would be restricted to the Animals and the Fruit&Veg classes, or, at least, to other specific categories, we would infer that the visual features here considered are crucial for the definition of some peculiar classes of objects only. This would be in line with the sensory-functional approaches (i.e. Warrington & Shallice, 1984; Warrington & McCarthy, 1987 -see paragraph 4.2.1.2), which claim that the sensory information plays a decisive part in the living things' categories.

In any case, contrary to the healthy subjects' findings, the contribution of the colour and, in particular, of the texture, seems to be important at least for the Fruit and Vegetables and the Animals. In the priming studies presented in the previous chapter, we concluded that the two attributes can play a specific facilitation on object categorization, only when they are presented bound together (see paragraph 3.8.1). Here we found a different results, since it seems that the texture can have a role in facilitating the recognition of some sub-categories even if it is presented separate from the colour.

We would suggest that these features are probably stored as a unique representation, which has to be completely activated in order to perform fast and highly demanding tasks; on the contrary, when time is given and the task is not so difficult, these representations can be partially accessed, so that a single dimension can be sufficient in order to facilitate the object recognition. In other words, in our interference tasks (3.6, 3.7), where the time given for recognition is very brief, a partial representation of the surface features of objects (such as in the pure texture and pure colour tasks- see 3.7) is not sufficient in order to activate other levels of representation (i.e. conceptual knowledge). In the same tasks, when the complete representation is given (i.e. 3.6), it can serve as a trigger for the activation of other semantic dimensions, even if the response-timing is forced.

(2) The second aim of this work was to investigate the relationship between shape and visual features, testing the hypothesis that the visual

attributes can be represented separately from the form of the objects (structural descriptions). In paragraph 4.1 we assumed that studying patients with a semantic deficit (vs. agnosic ones) would exclude the possibility that the object form recognition was impaired (at least not at the category level). Actually, our patients are able to recognize objects at class level: that is, they are able to say that a lion is an animal, or that a strawberry is a fruit. However, they are defective in the recognition and naming at exemplar level, revealing specific difficulties with particular classes of objects (i.e. living things). They also showed a strong difficulty in recognizing the details of the objects when presented alone, or when they have to be associated with the corresponding object-form. This finding would be interpreted as the impossibility of the patients in retrieving visual features without the co-occurrence of the corresponding form; furthermore, this also suggests that the two dimensions (i.e. shape + visual features) have to be bound together in order to be recognized by these patients. What does this mean? In our opinion, if the visual features were stored bounded with the shape, recognizing them would not be so difficult for the patients, at least for the very familiar items. Moreover, if they are stored linked with the shape dimension, we would not expect a selective loss of these aspects. On the contrary, if the visual surface features are stored separately from the shape-dimension, we can admit a selective loss of these aspects. The selective loss would interfere with all the tasks in which they have to be re-activated in order to succeed a refined object processing and to access a complete semantic representation of the object itself. Moreover, only if the representations of the surface properties and form-information are stored separately, we are allowed to admit that patients can recognize and retrieve information about objects for which they are not able to retrieve the surface information. This happened for our patients, in particular for MU, for the Textiles category: they were able to perfectly retrieve information about the shape of the objects or more general verbal knowledge about them, but they failed in tasks involving the corresponding surface features.

This point will be further discussed in the next paragraph, with reference to our tentative model.

(3) Our work aimed also to understand the representational status of the surface features: are they part of a pre-semantic structural description (even if separately stored) or can be they considered as semantic information? This problem regards also the possible existence of a visual semantic system within the conceptual knowledge store. We previously discussed this point with reference to our healthy subjects' investigation and with respect to the literature about this issue (see 3.8.2). Our priming experiments brought us to the conclusion that the visual features can be thought as semantic information, since they contribute to some semantic tasks (facilitating their succeeding). We claim that the results of the neuropsychological investigation can sustain this idea, since the patients clearly showed a specific problem in recognizing and managing the visual surface features, even when they were quite good in tasks involving the corresponding. In the first development of the SFT (i.e. Warrington & Shallice, 1984; Warrington & McCarthy, 1987) the authors assumed that the visual attributes of objects are semantic information (see 4.2.2). However, we previously discussed the lack of a clear theory about the specific nature of shape and other visual attributes of objects, reporting opposite interpretations of findings on visual information loss in patients. For instance, Capitani et al. 2003 reported the existence of patients who show a dissociation between the form-knowledge and the other visual attributes, finding that sustains at least the separate representation of the structural descriptions and the visual semantics; on the contrary, Coltheart et al. (1998) claimed that the structural descriptions and the visual information in general correspond to a unique store, recruited for different tasks.

Our findings seem more in line with Borgo & Shallice (2003), who claimed that the visual specific attributes defining the mass kinds (i.e. colour, surface and texture properties) were defective in their patients, determining the category's vulnerability, such as in the case of the living things' class. Our results are in line with those of Borgo & Shallice, since we found a specific impairment of the visual surface attributes relative to the objects; moreover, we found that the loss of these aspects is not restricted to particular classes of objects, but can be extended to all the categories (including for instance the Textiles, the Balls etc.). We can't exclude, in any case, that the loss of visual attributes can play a differential part in the deficit for living and non living things, since we didn't investigate in detail this hypothesis.

4.6.3. Fitting the model with our results and with the literature

In the model described in 3.8.3 (see Figure 21, reported here afterwards), we suggested that the semantic system includes both the abstract-verbal knowledge and a Visual Semantic store, which in turn contains all the specific visual information about a particular object. In this, we are in line with the SFT-like theories, which propose a fractionation of the semantic store according to the modality of acquisition of the information. In our model, no assumptions about a possible categorical fractionation of the semantic memory are made, even if, actually, they are not excluded as well.

The model predicts the existence of a pre-semantic store, containing the gross visual information about the form and the surface information strictly needed in order to recognize the objects. This store broadly corresponds to the Structural Descriptions (as usually named in the literature), but it also specifies other components, more detailed and relative to all those properties which are needed for the recognition: i.e. Specific Parts of the objects, the prototypical colour and the gross surface properties.

The model thus proposes the existence of a sort of double-representation of some kinds of visual information, so that, for instance, the fine details, the specific colour, the surface features of objects are stored in a further visual store (i.e. Visual Semantics), were they are codified as semantic information. This information, which is crucial in order to define objects at a conceptual level, broadly corresponds, in our opinion, to the visual attributes that Warrington & McCarthy (1987) referred to, when discussing the representational status of particular kinds of objects in the semantic system (see paragraph 4.2.2).

We will briefly try to comment our neuropsychological findings in light of this model.

We excluded a general problem of recognition in our patients. In other words, we assumed they were able to access the Structural Descriptions; in the case of MU, who was the more defective patient, this was true at least for the recognition of objects at the category level.

However, we found that both patients were impaired in the naming tasks, involving both living and non living things. This would mean, alternatively, that the patients would not be able to recognize the objects (at the pre-semantic level) or that they were not able to access the Abstract-verbal Knowledge or that this last store was disrupted. It is worth noting that both MU and SER had a quite good performance (well above chance) with some categories, even if they were down with respect to their control subjects. This excludes the hypothesis that they were impaired in the lowest levels of recognition (i.e. early visual process or pre-semantic levels).

We excluded that the difficulties in all our tasks were due to word-retrieval deficits (i.e. problems of access to the Lexical Representations), since no gross differences emerged between the naming and the matching tasks, which were considered as facilitated versions of the naming (alternatives of answer were given).

As a main result, we found that both patients were much more impaired with the details than with the entire objects, in both the naming and the matching tasks. Crucially, the effect was not restricted to the living things' classes (i.e. Animals and Fruit&Veg), but it extended to a non living things' category, i.e. Textiles. This result is important, since it does not support theories (such as the original SFT formulation), which claim that in the patients showing semantic deficits, the visual attributes are lost mostly in the case of the living things.

With respect to the model, we can suggest that our patients have a deficit in the Visual Semantics, where the information about the specific visual appearance of objects is stored. This deficit prevents MU and SER in recognizing the specific surface properties of objects (e.g. the texture) when they are presented without the shape-dimension[60]. The fact that this information is semantic in nature is particularly confirmed by the fact that the classes which need a more refined level of visual information in order to distinguish between their members, were characterized by the worst performances (e.g. Balls). We think that Warrington & McCarthy (1987) were correct in saying that particular visual attributes, such as the colour, the texture and other surface information, play a strong part in defining some peculiar classes of objects, such as the Fruits and Vegetables. Our results are in line with their position; however, we also found that the same kind of visual information can be lost for other classes (i.e. artefacts), even if the loss of visual surface features is not crucial for the recognition of their elements.

Thus, we would sustain more the intercorrelational models of semantic representation, which state that the properties of objects are linked each other and with the object-shape with differential weights. Some of these models (see 4.2.1.4) make distinctions between the artefacts and the living things' categories, proposing a differential kind of intercorrelation between shape/function/visual attributes for the diverse categories (i.e.: De Renzi & Lucchelli, 1994; Buxbaum & Saffran, 1998; Tyler & Moss, 1997). However, these kinds of models do not predict similar levels of visual information loss in patients for opposite categories. The same critic has been put forward the SFT-theories, which predict differential levels of visual information loss for the living and the non living things (see Caramazza & Shelton, 1998 for the critics to the SFT).

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[60] When testing MU we had also the counterproof that he was not able to check about the correctness of some objects in which the surface attributes were changed within the correct shape: for instance, we was not able to say if a completely smooth lemon was correct or not, even if he correctly identified it as a lemon.

Our results do not sustain the idea of a differential amount of visual information loss in patients showing semantic deficits (and semantic dissociations). Moreover, we found that some artefacts categories (i.e. Musical Instruments and Balls) can be damaged at the same level than the living things in patients showing a general dissociation between the domains of knowledge. However, the same patients showed the quite same degree of impairment for the living and the non living things, when the details of the objects were considered, showing a selective impairment of the visual knowledge about quite all the classes.

Borgo & Shallice (2003) found a similar pattern of results when investigating MU's performance with a novel class of objects (the Mass Kinds –see 4.2.3): in particular, they proposed that MU had a specific problem with the visual attributes which are determinant in order to analyse the mass kinds; furthermore, they also commented about the part played by the functional information in sustaining the artefacts categories representations. Since the living things and the mass kinds had no strong functional specification, MU did not benefit of this kind of information in retrieving representations form these two domains. Borgo & Shallice (2003) took into account the mass kinds in order to investigate patients' performance with a non living things' category which is not strongly defined by the shape properties, whereas by the sensory attributes of its elements. Similarly, we took in consideration the visual surface features of objects without concentrating to the classical living things' classes. Crucially, we used a class of artefacts, which don't lack the shape dimension (i.e. Textiles), but which elements are at the same time strongly defined by visual surface properties. This allows a direct comparison between this class and other living things sub-categories, such as the Animals, which share high amounts of shape-features, whereas they are distinguished on the basis of surface specific details. Moreover, we also added a class of objects (i.e. Balls), which are not distinguishable at all on the basis of the shape, with few exceptions, but they can be identified at exemplar level only using refined visual information. In our opinion, this specific class of objects can resemble the Fruits and Vegetables.

In any case, ~~similarly to~~ Borgo & Shallice (2003), our patients showed (a) no differences across categories with respect to the amount of visual information loss; (b) differences across categories when the most visually-defined objects were considered.

In order to explain this pattern of results, we favour distributed accounts of object representation (see 4.2.1.5), such as the Damasio's Convergence Zones Theory

(1989) and the model proposed by Simmons and Barsalou (2003). Both these accounts propose a distributed organization of the properties of objects, with the complete representations deriving from the simultaneous activation of feature maps. The two models differ with respect to the nature of these feature maps, but they share the central idea that a single object representation is the result of the activation of different patterns of features within a more extensive space. Simmons & Barsalou (2003) model is able to explain the arising of peculiar effects of information or category dissociations, on the basis of the differential involvement of specific kinds of "convergence zones" (see 4.2.1 for details).

We think that the complexity of patients' behaviour found also in our study can fit with these kinds of models. Furthermore, when taking into account our patients' performance and the localization of their cortical lesion (see 4.3.3.2 and 4.3.4.2), we would claim that our results fairly fit with Tyler et al. (2004). As discussed in 2.4.3, these authors proposed a model that is in line with both Damasio (1989) and Simmons & Barsalou (2003); furthermore, they considered evidences coming from localization studies on the monkey (e.g. Bussey et al. 2002), which sustain the idea of hierarchically organized object representations within the occipito-temporal stream.

According to this position, the lesion in the anterior aspects of the temporal lobes can determine a specific impairment of fine grained visual information, which is crucial in order to distinguish and recognize the living things. however, differently from other neuropsychological models, this authors don't specify a peculiar categorical organization of knowledge, but they just claim that the lesion, involving specific visual information, can have a differential weight for diverse categories of objects. Crucially, in their neuropsychological investigation, these authors used different categories of objects, which were chosen with respect of the diverse degree of structural similarity. In other words they didn't take into account visual properties different from the shape-dimension. However, we think that Tyler et al. (2004) position can fairly fit with our results and in particular with the finding of a generalized loss of visual surface properties, independently from the category of belonging of objects.

Moreover, as underlined by Tyler et al. (2004), the kind of task requirements can be determinant in revealing specific deficits in patients. In other words, and referring to our investigation, a naming or a matching task involving the complete objects (i.e. the Naming of Items and the Matching tasks-Items) would need different kinds of representations, than a naming or a matching task involving the details of the same objects, since these tasks require a finer visual discrimination of the stimuli (and the retrieval of finer visual representations from memory).

We would suggest that the hierarchical organization of visual attributes within the occipito-temporal stream (proposed by Tyler et al 2004) can fit with the organization of the components of our tentative model (Figure 21).

In detail, the early visual process and the reconstruction of a Gross Structure (binding of visual features) is likely to take place in the posterior areas (occipital cortex), whereas the object recognition at a pre-semantic level (corresponding to the Structural Description + Specific Parts + Prototypical Colour + Gross Surface Features) can correspond to the subsequent activation of posterior temporal areas; furthermore, the anterior temporal lobes would be involved in the Visual Semantics activation. More and more anterior areas would be activated in the Abstract verbal Knowledge retrieval and in the eventual lexical access (Lexical Representations), that is supposed to require more frontal regions.

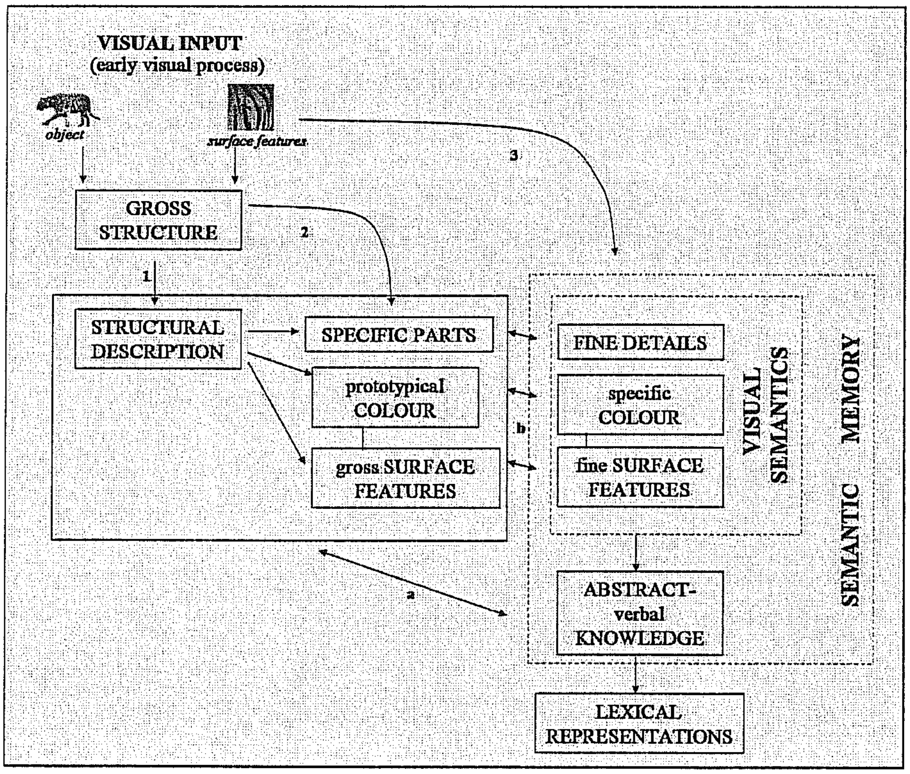

Figure 21. A tentative model of object representation.

As a final point, we would take into account the problem of the relationship between the Structural Description and the Visual Semantics. As previously discussed, there is no agreement about this issue (see 4.6.2 -3-), even if it has been claimed that the two stores can be considered as separate, as pointed out by Capitani et al. 2003. However, in their review of category specificity literature, the same authors said that "...we neither have a corroborated theory about the relationship between the representations stored in the structural description system and those stored in the semantic system(s), nor do we know exactly how these representations dynamically interact while a subject performs a cognitive task" (Capitani et al., 2003: page 216).

With our model, we claim that the Visual Semantics can be activated by the Structural Description or, alternatively, by the direct presentation of visual properties in the absence of the form of the object. In our view, this is corroborated by the possibility of a selective loss of visual surface aspects in patients, and it further sustains the idea of a separate and independent semantic representation of these properties.

5. Conclusions

Visual recognition is a complex cognitive ability that requires to identify and process diverse kinds of information, starting from the global shape of the object, its dimensions, its parts and details, but also its colour and its surface properties (see Chapter 2). The confrontation of the perceived object with a correspondent representation in memory allows the system to recognize it as something just encountered and to give it a specific meaning: in other words, this confrontation allows *recognition*.

The present work addressed the issue of object representation in memory; in particular, we would like to investigate the role played by the surface properties of objects (i.e. colour, surface pattern, texture) in the object representation.

The literature about visual object recognition showed no clear conclusions about the issue of visual features' status in memory. In detail, as pointed out in Chapter 2, there is no agreement about the relationship between shape and other kinds of visual information (i.e. colour) in object representation, with some authors sustaining the necessity of the shape in recognizing the surface visual aspects (e.g. Walker & Hinkley, 2003), and others negating this needing (e.g. Hanna & Remington, 1996). Moreover, whereas several studies take into account colour, texture has been less studied (Kovacs et al. 2003; Barrett et al. 2001).

Similarly, the neuropsychological literature presents some controversial results and interpretations about the nature of visual features: near theories which give strong importance to the visual information to the conceptual representation (i.e. Warrington & Shallice, 1984; Warrington & McCarthy, 1987; Borgo & Shallice, 2003), there are other approaches which consider the visual properties of objects as part of the pre-semantic information (i.e. Humphreys & Riddoch, 1988). The specific role of visual features in the semantic representation of objects is expressly taken into account by few of the former models, and only some studies specifically consider the issue of the relationship between the possible visual semantic system and the structural description level (e.g. Coltheart et al. 1998).

5.1. Summary of thesis

This thesis had three aims, which were to test the hypothesis of a separate representation of visual surface features and the possibility that these representations can be accessed independently from the structural descriptions; moreover, we would like to investigate whether the surface properties of object are stored as a piece of semantic information.

We tested our hypothesis using two different approaches: the first was to investigate the normal functioning of the object recognition using priming paradigms; the second was to study the damaged system, trying to explore two neuropsychological patients' behaviour when forced to use the critical representations.

In the priming studies we used the critical features to prime the objects to which they belong or the correspondent words. In the 6 experiments developed, we used the always the same primes, which depicted the critical visual surface properties of the objects, whereas in the diverse experiments we changed the kind of task (i.e. object decision, object/word categorization), the kind of target (pictures vs. words) and the SOA, that is the time passing between the prime and the target presentation (200 ms in the experiments 1-3, 0 ms in the experiments 4 and 5, respectively).

The priming studies showed that the a detailed surface attribute can prime the object of belonging or the correspondent word. The same priming effect was not observed for the semantically related primes (i.e. surface features of objects taken from the same or the opposite category of the target), sustaining the idea of a complete recognition of the prime itself. Furthermore, we also found that the surface details have to be presented as a bounded instance (vs. separate single features) in order to determine priming effects.

These findings were interpreted as an evidence in favour of theories which sustain the specific contribution of such features in object representation (Ostergaard & Davidoff, 1985; Price & Humphreys, 1989). Moreover, and differently from other positions (i.e. Walker & Hinkley, 2003), we interpreted our findings in support of the idea of a separate representation of the surface features from the structural descriptions. This conclusion was corroborated by the emergence of priming effects in the Word Categorization experiment (where the target was a word) and, furthermore, by the existence of interference effects due to the semantically related primes in the Picture-Word Compounds experiments. The former result was interpreted as the proof of an interaction of the surface details with high levels of object representation (i.e. abstract knowledge accessed by the words), without the necessary shape-mediation (since the target was not a picture). The latter result was interpreted as an evidence in favour of a semantic interpretation of the primes, on the assumption that, if the primes were not interpreted as part of a conceptual representation, no effects of interference would be expected by the semantically-related primes. Thus, these findings seemed also to fulfil the third aim of the experiments, that was to test hypothesis of the possible semantic nature of the visual surface features representations.

Moreover, the lack of facilitation effects in the interference paradigms when the colour and texture properties were presented separately sustain the idea of a complex representation of such features in memory, strengthening the hypothesis of the semantic format of such information.

These conclusions were also corroborated by the finding of a general time-modulation on the results: the longer tasks were in fact characterized by the strongest priming effects, probably because the more time allowed the access to higher levels of representation. Moreover, the time was the critical factor in determining the differences sometimes observed between the Fruits and Vegetables and the Animals: the different behaviour of two categories could be due to their different level of structural similarity (Price & Humphreys, 1989) together with the different kinds of representations accessed by the diverse tasks (Ostergaard & Davidoff, 1985) as a function of time.

In the second part of the thesis we studied two HSE patients, who both showed a semantic impairment in the general cognitive assessment, even if with some differences. They both presented with lesions in the temporal lobes, in areas corresponding to the regions identified for the refined visual information retrieval and processing. Moreover, they both presented with category specificity (even if in different degrees and at different stages of their illness). In the introduction to Chapter 4 we discussed the reason why studying category specific patients can give important insights about visual knowledge representation. The main point is that some theories, including SFT (Warrington & Shallice, 1984; Warrington & McCarthy, 1987) and some other distributed accounts (i.e. Tyler et al., 2004; Simmons & Barsalou, 2003), explain category specific deficits considering the role that some kinds of properties (i.e. visual ones) can play in defining the living things elements. Furthermore, some authors gave a strong importance to the surface features, such as colour and texture, in defining the living things categories, and claim that the selective loss of these categories' knowledge can be strictly linked to the damage to this kind of information (Warrington & McCarthy, 1987; Borgo & Shallice, 2003).

We would like to test the aims of our study on these patients, trying to verify whether the knowledge about the visual properties of objects is damaged (even if the possible deficit does not emerge in the standard testing).

Our patients were thus presented with a series of standard naming and verbal-to-visual/visual-to-verbal matching tasks, in order to further explore they difficulties in retrieving knowledge about some classes of objects, taken from both the living and the non living things' domains. Subsequently, they were presented with the same tasks, but involving the specific visual properties which are the focus of our study. So, for instance, they were asked to match the skin of an animal with the corresponding name, or the detail of a cloth with the corresponding object name.

Crucially, we decided to include in this study also objects taken from the artefacts domain. This idea derived from the study by Borgo & Shallice, who claimed that Mass Kinds elements share with the living entities their strong dependence on the visual features, which are needed in order to distinguish between the exemplars of the class. This characteristic is particularly salient in the case of the mass kinds, since they lack the form-dimension. We further expected, contrary to other correlational approaches (Tyler & Moss, 1997), that patients would show a similar degree of loss of visual attributes for all the considered categories, even if the impact of this loss would be determinant for some categories and not for others.

The neuropsychological investigation showed a generalized problem of both patients with quite all the categories considered. However, both MU and SER showed to be unimpaired with respect to their control subjects, at least in specific conditions (in particular MU when Tools were presented). Moreover, they both showed to be well above chance in some specific conditions, excluding the hypothesis of a general difficulty effect and allowing at least to draw some general conclusions based on the qualitative analysis of the patients' performance.

When the conditions employing the Items and those involving the Details were compared, we found that both patients had a worse performance with the Details. The fact that this difficulty was not confined to the living things classes corroborated the idea that the visual attributes of objects can be lost irrespectively from the status of the shape-representation.

We further concluded that the fact that our patients were impaired in semantic tasks, whereas able to recognize the objects (at least at the category level), reinforces the idea that the visual features can be part of the semantic knowledge.

5.2. A model for visual object representation

On the basis of the priming studies and the neuropsychological investigation findings, we proposed a tentative model of object representation, which is described in Figure 21.

Contrary to some approaches about object recognition (i.e. Humphreys & Riddoch, 1988; Coltheart et al. 1998), the model predicts the existence of a visual semantic store which is not correspondent to the Structural Description level. We assume that the Visual Semantics is the store for the visual refined information which is needed in order to specifically define the objects and to distinguish between similar exemplars (in line with Warrington & McCarthy, 1987). We do not assume that the general Semantic System, which contains the Visual Semantics as a sub-system, is categorically organized, but we can't neither exclude this possibility on the basis of our study.

The model predicts that the early visual processing of the visual surface features, even when presented without the co-occurring object form, can directly access the Visual Semantics, activating the visual representations corresponding to those properties present in the stimulus. This assumption has two consequences: (a) the visual properties can be represented independently from the shape; (b) the visual features are semantic information, in strict communication with higher abstract levels of representation (i.e. Abstract Knowledge, Lexical Representations).

The model also allows a sort of double-representation of the same information: for instance, colour is represented at the Structural Description level, but then it is specified in the Visual Semantics. For instance, a lemon is defined by its shape and its colour (i.e. *oval + yellow*) at the Structural Description level, whereas more refined information about the same dimensions is stored in the Visual Semantics (i.e. *not perfect oval form, rough surface very light, yellow* etc.). This doubling of the visual information can fit with the existence of patients showing visual agnosia, but still able to access the visual representations in verbal questionnaires (i.e. visual agnosic patients) and, at the same time, with the existence of patients with semantic problems, who are able to recognize the objects, but unable to retrieve only some kinds of information about them, in both visual and verbal tasks (e.g. the patients here studied).

We discussed both the priming results and the neuropsychological findings in light of the literature about conceptual representation, favouring, in both cases, distributed accounts (Simmons & Barsalou, 2003; Damasio, 1989; Tyler et al. 2004). In particular, we discussed Tyler et al. (2004) position, according to which the concepts and the object representations correspond to distributed representations across the occipito-temporal ventral stream. This position originates from a connectionist model of monkey perirhinal cortex organization (Bussey & Saksida, 2002) and from broad models about conceptual organization in the humans (Damasio, 1989; Simmons & Barsalou, 2003). Tyler et al. suggest a hierarchical organization of visual representations within the ventral stream, with the gross information stored in the posterior areas of the occipito-temporal regions, and the more refined information stored in the anterior aspects of the temporal cortices. Moreover, they follow Price & Humphreys (1989) in assuming that the task requirements and the structural characteristics of the category of belonging of objects (defined in terms of structural similarity or dissimilarity of the class-exemplars) are crucial variables in determining the arising of category-specific effects and specific patterns of impairment in patients.

In conclusion, we suggest that the findings of both the priming studies and the neuropsychological investigation can sustain the idea that the visual surface features of objects are stored independently from the Structural Description -with respect to both the store and the format-. We also claim that it is reasonable to think that the visual properties of the objects correspond to semantic representations, which can be directly accessed (in the Visual Semantics, where they are stored) by the early visual processing of the corresponding stimuli. Moreover, the visual representations in the Visual Semantics could, independently from the Structural Description, access other kinds of abstract information, different from the visual one, and they can also access the Lexical Representations. We claim that such conclusions are in line with recent works on both normal subjects and neuropsychological patients, which are based on broad distributed hierarchical models of conceptual representation (Damasio, 1989; Simmons & Barsalou, 2003; Tlyer et al. 2004).

5.3. Limits of the studies and prospective

Behind some limits of the priming studies here described, we still think that the paradigms we used and, in particular, the kind of material employed (i.e. visual features belonging to the objects used as targets), represent a novel approach to the issue of visual object representation.

Certainly, the materials need to be further ameliorated. In particular, the categories of objects employed in the study need to be enlarged; moreover, familiarity and frequency of material have to be taken into account. Furthermore, we think that changes in the Baseline and, more importantly, in the definition of Same vs. Different Category primes would sort differential and stronger results. Maybe, contrasting completely different categories of knowledge (i.e. animals vs. artefacts) in the categorization tasks would determine stronger effects; moreover, using Different Category primes taken from a completely different domain would determine a strengthening of the effects.

With respect to the second part of the work, we think that the neuropsychological findings, despite going in the same direction of the priming experiments, had the gross limit that both MU and SER were impaired with respect to their control subjects in quite all the conditions. Thus, the conclusions attempted in the neuropsychological study need further and more controlled investigations, on a larger group of patients, maybe showing stronger effects of visual semantic impairment.

We think that the questions addressed in this thesis would be further tested studying also agnosic patients, who are able to access semantic knowledge, as previously suggested (see 4.1).

The materials here used would be employed in other kinds of investigations and would become part of broader batteries addressing visual semantic knowledge. This possible battery would comprehend object shape-stimuli, surface features-stimuli and verbal questions about the same material. Moreover, we think that such a battery would take into account the novel categories of knowledge identified by Borgo & Shallice (2003), since they seem to be strongly defined by the same kind of attributes here explored. Furthermore, Borgo & Shallice methodology could be applied to our material, developing a more comprehensive study.

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APPENDIX A

Stimuli list and target-prime association for each item of Fruits/Vegetables and Animals categories

Num.	Category	Sub-category	Item (Target and Identity Prime)	Same Category Prime	Different Category Prime (visually corresponding to...)
1	*Fruits and vegetables*	*Fruits*	*pineapple*	*strawberry*	*green leaf (cucumber)*
2	*Fruits and vegetables*	*Fruits*	*watermelon*	*banana*	*basket1 (artichoke)*
3	*Fruits and vegetables*	*Fruits*	*lemon*	*pineapple*	*red fitted carpet (strawberry)*
4	*Fruits and vegetables*	*Fruits*	*apple*	*banana*	*doormat (pineapple)*
5	*Fruits and vegetables*	*Fruits*	*melon*	*apple*	*red leather (pepper)*
6	*Fruits and vegetables*	*Fruits*	*strawberry*	*pear*	*dark green leaf (watermelon)*
7	*Fruits and vegetables*	*Fruits*	*pear*	*strawberry*	*basket2 (melon)*
8	*Fruits and vegetables*	*Fruits*	*banana*	*melon*	*dense web (onion)*
9	*Fruits and vegetables*	*Vegetables*	*artichoke*	*carrot*	*yellow wood (banana)*
10	*Fruits and vegetables*	*Vegetables*	*carrot*	*cucumber*	*light green sponge (pear)*
11	*Fruits and vegetables*	*Vegetables*	*pepper*	*artichoke*	*orange sponge (carrot)*
12	*Fruits and vegetables*	*Vegetables*	*cucumber*	*onion*	*yellow sponge (lemon)*
13	*Fruits and vegetables*	*Vegetables*	*onion*	*pepper*	*red textile (apple)*
1	*Animals*	*European*	*pig*	*leopard*	*grey velvet (mouse)*
2	*Animals*	*European*	*cow*	*hippopotamus*	*"thorn pattern" (hedgehog)*
3	*Animals*	*European*	*frog*	*hedgehog*	*basket3 (leopard)*
4	*Animals*	*European*	*hedgehog*	*rhinoceros*	*grey silk (hippopotamus)*
5	*Animals*	*European*	*turtle*	*pig*	*grey stone (rhinoceros)*
6	*Animals*	*European*	*mouse*	*giraffe*	*b&w flag (zebra)*
7	*Animals*	*Exotic*	*crocodile*	*zebra*	*grey jeans (elephant)*
8	*Animals*	*Exotic*	*elephant*	*tiger*	*football ball (cow)*
9	*Animals*	*Exotic*	*giraffe*	*mouse*	*grey wool (turtle)*
10	*Animals*	*Exotic*	*hippopotamus*	*crocodile*	*parquet (giraffe)*
11	*Animals*	*Exotic*	*leopard*	*cow*	*military textile (crocodile)*
12	*Animals*	*Exotic*	*rhinoceros*	*frog*	*wood (tiger)*
13	*Animals*	*Exotic*	*tiger*	*turtle*	*rose textile (pig)*
14	*Animals*	*Exotic*	*zebra*	*elephant*	*green marble (frog)*

APPENDIX B: DATA

Table a. Latencies of 20 subjects (average in ms) in Experiment 1 –Object Decision

OBJECT DECISION		RTs means *(sd)*	
TARGET TYPE	**PRIME TYPE**	**FV CONDITION**	**ANIMALS CONDITION**
Total	**IDENTITY**	672.98 *(120.88)*	668.29 *(103.95)*
	SAME CATEGORY	698.65 *(150.64)*	674.37 *(110.26)*
	DIFFERENT CATEGORY	687.14 *(123.27)*	676.17 *(105.59)*
	BASELINE	703.39 *(140.31)*	667.13 *(106.05)*
Real	**IDENTITY**	660.53 *(130.71)*	661.28 *(112.30)*
	SAME CATEGORY	676.47 *(139.19)*	675.08 *(120.80)*
	DIFFERENT CATEGORY	664.40 *(125.38)*	663.52 *(117.25)*
	BASELINE	667.24 *(136.65)*	641.66 *(105.83)*
Unreal	**IDENTITY**	690.81 *(116.86)*	676.25 *(108.74)*
	SAME CATEGORY	729.23 *(177.06)*	676.59 *(111.66)*
	DIFFERENT CATEGORY	717.81 *(138.06)*	691.19 *(105.73)*
	BASELINE	747.21 *(167.86)*	691.93 *(113.45)*

Table b. Latencies of 20 subjects (average in ms) in Experiment 2 –Object Categorization

OBJECT CATEGORIZATION	RTs means *(sd)*	
PRIME TYPE	**FV CONDITION**	**ANIMALS CONDITION**
IDENTITY	559.95 *(61.56)*	577,16 *(76,43)*
SAME CATEGORY	576.08 *(77.15)*	598.69 *(83.82)*
DIFFERENT CATEGORY	570.12 *(64.16)*	597.62 *(79.66)*
BASELINE	590.75 *(76.29)*	588.99 *(84.82)*
Total	579.24 *(69.99)*	589.42 *(77.58)*

Table c. Latencies of 20 subjects (average in mSec) in Experiment 3 –Word Categorization

WORD CATEGORIZATION	RTs means *(sd)*	
PRIME TYPE	FV CONDITION	ANIMALS CONDITION
IDENTITY	642.33 *(107.62)*	675.51 (113.64)
SAME CATEGORY	650.48 *(100.09)*	719.15 (177.91)
DIFFERENT CATEGORY	652.44 *(117.84)*	687.31 (109.35)
BASELINE	661.60 *(109.54)*	689.62 (132.06)
Total	651.76 *(106.37)*	692.91 (130.42)

Table d. Latencies of 20 subjects (average in mSec) in Experiment 4-5-6 –Picture-Word Compounds Categorization

WORD PICTURE COMPOUNDS	RTs means *(sd)*		TEXTURE EXP: RTs means *(sd)*		COLOUR EXP: RTs means *(sd)*	
PRIME TYPE	FV CONDITION	ANIMALS CONDITION	FV CONDITION	ANIMALS CONDITION	FV CONDITION	ANIMALS CONDITION
IDENTITY	707.49 *(182.84)*	725.57 *(215.72)*	702.34 *(139.31)*	683.12 *(86.62)*	750.71 *(128.31)*	800.89 *(152.58)*
SAME CATEGORY	744.46 *(191.22)*	754.93 *(237.66)*	704.99 *(127.71)*	696.51 *(93.70)*	747.97 *(135.43)*	821.17 *(199.99)*
DIFFERENT CATEGORY	760.96 *(228.32)*	752.48 *(254.07)*	703.29 *(124.14)*	689.81 (85.86)	761.65 *(123.78)*	810.76 *(160.68)*
BASELINE	716.19 *(177.04)*	736.98 *(191.36)*	694.77 *(130.50)*	686.83 *(70.91)*	760.35 *(135.77)*	828.75 *(164.09)*
Total	732.45 *(193.55)*	742.53 *(222.57)*	701.40 *(127.25)*	689.12 *(80.55)*	755.25 *(127.50)*	815.48 *(166.37)*

APPENDIX C -MU's FIRST NEUROPSYCHOLOGICAL ASSESSMENT

Table a. General cognitive profile

Impaired performance on general tasks	
test	**score**
Performance IQ (WAIS[1])	91 ″
Elithorns' Perceptual Maze Test[2]	9.5 *
FAS (verbal fluency)[3]	2.8 *
Category Fluency[2]	3.5 *
Verbal Reasoning[2]	30.25 *
Visual Search[2]	42.25 **
Wechsler Memory Scale[a]	
Information	2 *
Mental Control	2 *
Logic Memory	0.5 *
Learning Pairs Associated	7 *
Digit Span Backward	4 **
Token Test (AAT)[°]	17 #

[1] Wechsler (1986); [2] Spinnler and Tognoni (1987); [3] Ghidoni, Poletti, Bondavalli (1995); [a] Wechsler (1948); [°] Luzzatti C., Willmes K., Bisiacchi P., De Bleser R., Faglia L., Mazzucchi A., Taricco M.. The Aachen Aphasia Test (1987); " lower limits; * score below 2sd nomral mean; ** score below 1sd normal mean; # mild impairment. Notice that only impaired performance is reported: for a complete MU's Assessment see Borgo & Shallice (2001).

Table b. Visual abilities

Impaired performance on visual tasks	
test	**score**
Street Completion Test[1]	5**
BORB[2]	
Object decision task: easy	16/32 *
Object decision task: hard	16/32 *
VOSP[3]	
Silhouettes	5/30^
Progressive silhouettes	16^
Object decision	14/20^
Incomplete letters	14/20^
DeVreese et al. Test of Colour Perception[°]	
Colour Naming	8.2 **
Colour Identification	8.01 *

[1] Spinnler and Tognoni (1987); [2] Riddoch and Humphreys (1993); [3] Warrington and James (1991); [°] De Vreese, Faglioni, Agnetti (1994); * score below 2sd nomral mean; ** score below 1sd normal mean; # mild impairment; ^ score below 5% cut -off. For a complete MU's Assessment: Borgo & Shallice (2001).

Table c. Semantic knowledge

	Living Things			Non Living Things		
	MU	**Control (SD)**	***z* (*P*)**	**MU**	**Control (SD)**	***z* (*P*)**
Visual confrontation	33*	75 (21.7)	-1.9 (<0.05)	75	76 (20.4)	-0.1 (=0.5)
Functional description	35*	73 (24)	-1.6 (=0.05)	80	69 (20.2)	+0.6 (<0.5)
Perceptual description	20	49 (22.5)	-1.3 (=0.1)	65	54 (29.3)	+0.4 (<0.5)
Word-picture matching	61*	87 (14.6)	-1.8 (<0.05)	100	94 (7.9)	+0.7 (<0.5)
Picture-word matching	72***	94 (0)	-10 (<0.0001)	83	83 (17.6)	0.00 (=0.5)
Functional attributes	73**	88 (7.3)	-2.1 (=0.01)	83	87 (10.2)	-0.4 (<0.5)
Perceptual attributes	74*	88 (9)	-1.6 (=0.05)	93	91 (8.2)	+0.1 (<0.5)

* Significant at the 0.05 level; ** Significant at the 0.01 level; *** significant at the 0.001 level; table rearranged from Borgo F. dissertation Thesis (2000).

APPENDIX D- MU SECOND NEUROPSYCHOLOGICAL ASSESSMENT

Table a. General cognitive profile

test	score
WAIS[1]	
WAIS Total IQ	**64 ***
WAIS Performance IQ	**82 ****
Information	---
Digit span	5
Vocabulary	3
Arithmetic	---
Comprehension	5
Similarities	4
Picture Completion	6
Picture Arrangement	5
Block design	6
Object Assembly	7
Digit symbol	6
Raven Progressive Coloured Matrices[2]	**29/36**
Intelligence Tasks[3]	44/60
Sentence Generation[3]	8/18*
Verbal Fluency (FAS)[5]	13*
Categorical Fluency[3]	
Digit Span forward[3]	5
Digit Span Backward[3]	2*
Story recall[3]	4.4/16*
Verbal Span[3]	4
Verbal Span[3]	4
Trail Making Test A[4]	55"
Trail Making Test B[4]	impaired
Visual Search[3]	52/60
Elithorns's Perceptual Maze Test[3]	12.5/16

[1] Wechsler (1986); [2] Raven (1962); [3] Spinnler and Tognoni (1987); [1] Giovangoli, Del Pesce, Mascheroni, Simonelli, Laiacona, Capitani (1996); [2] Ghidoni, Poletti, Bondavalli (1995); * below 2sd normal mean; ** below 1sd normal mean.

Table b. Visual abilities and object recognition

De Vreese et al. Test for Colour Perception[1]	
Sub-test	**raw accuracy**
HISHIARA test	19
Painting-a	6*
Painting-b	8*
Painting-c	3*
Painting-d	5*
Wrong color recognition-a	7*
Wrong color recognition-b	5*
Wrong color recognition-c	6*
Fluency: colors	8
Fluency: animals	12
Fluency: fruits	6*
Fluency on verbal color	10*
Fluency on visual color	9
Colors associated to objects-a	8*
Colors associated to objects-a	6*
Colors associated to objects-a	3*
Colors associated to objects-a	4*
Naming of isolated colors	8
Hue comparison (imagery)	5*
Color comparison (imagery)	3*
Benton's Face Recognition Test[2]	
Short Form (equivalent score)	<25#

BORB[3]	
Sub-test	**raw accuracy**
Length matching task-A	20/30*
Size matching task-A	27/30
Orientation matching task-A	25/30
Position of gap matching task	28/40*
Overlapping figures	50/54
Minimal feature matching	24/25
Foreshorten matching	25/25
Object decision: total	80/128*
Easy A	19/32*
Easy B	22/32*
Hard A	17/32*
Hard B	22/32
Matching items	29/32
Matching-associative	23/30*
Naming short version	3/15*
Naming long version	37/76*
VOSP[4]	
Sub-test	**raw accuracy**
Screening test	20/20
1. Incomplete letters	20/20
2. Silhouettes	4/30^
3. Object decision	17
4. Progressive silhouettes	15$
5. Dot counting	10/10
6. Position discrimination	18/20
7. Number location	7/10
8. Cube analysis	10/10

[1]De Vreese, Faglioni, Agnetti (1994); [2] Benton, Silvan, Hamsher, Vamey, Spreen (1992); [3] Riddoch, Humphreys (1993); [1] Warrington, James (1991); ^ score below 5% cut off; $ score below 25% cut off; * score below 2sd normal mean; # strongly impaired.

Table c. Language abilities

BADA[1]				
sub-test	**ACCURACY**	**% accuracy**	**ERRORS**	**score**
AUDITORY COMPREHENSION (nouns)	38/40	95%	2/40	+/-
AUDITORY COMPREHENSION (verbs)	19/20	95%	1/20	+
VISUAL COMPREHENSION (nouns)	38/40	95%	2/40	+/-
VISUAL COMPREHENSION (verbs)	20/20	100%	0/20	+
controlled DESCRIPTION on visual presentation	10/10	100%	0/8	+
DESCRIPTION on visual presentation	6/8	75%	2/8	+/-
grammatical VUSUAL COMPREHENSION	43/45	98%	1/45	+
grammatical AUDITORY COMPREHENSION	57/60	95%	3/60	+/-
NAMING on definition	14/16	87,50%	2/16	+/-
NAMING on visual presentation (nouns)	15/30	50%	15/30	-
NAMING on visual presentation (verbs)	17/28	61%	11/28	-

[1] Batteria per l'Analisi dei Deficit Afasici. G.Miceli, A.Laudanna, C.Burani, R.Capasso, CESPAG (1994).

APPENDIX E -SER's FIRST NEUROPSYCHOLOGICAL ASSESSMENT

Table a. General cognitive profile

Impaired performance on general tasks	
test	**score**
Total IQ (Wais[1])	83**
Performance IQ	61*
Category Fluency[2]	19*
Verbal Reasoning[2]	43 **
Visual Search[2]	44/60**
Story recall[2]	7/16*
Corsi's supra-span[2]	11.04 *
Busche-Fuld Test[2]	
Total Recall	52 *
Non-random recall	0 *
Delaied recall	2 *
AAT (Aachen Aaphasie Test)[3]	
Token test	2/50#
Naming	72/120@
Comprehension	89/120$
TEA (Test of Everyday Attention)[4]	
Cue-allert	30 *
Without cue-allert	29 *
Simple RTs	37 **
Divided attention	35 **
Ideational Apraxia[6]	12/14 ^

[1] Wechsler (1986); [2]Spinnler and Tognoni (1987); [3]Luzzatti C., Willmes K., Bisiacchi P., De Bleser R., Faglia L., Mazzucchi A., Taricco M.. The Aachen Aphasia Test (1987); [4] TEA XXX; [6] APRAXIA; * score below 2sd normal mean; ** score below 1sd normal mean; ^ below 5% cut-off; # deep deficit; @ medium deficit; $ mild deficit.

Table b. Visual abilities

Impaired performance on visual tasks	
test	**score**
BORB[1]	
Object decision task: hard	19/30*
VOSP[2]	
Silhouettes	4/30*
Number location	5/10*
Object decision	5/20*
Cube analysis	7/10^

[1] Riddoch and Humphreys (1993); [2] Warrington and James (1991); * score below 2sd normal mean; ^ score below 5% cut -off.

APPENDIX F -SER's SECOND NEUROPSYCHOLOGICAL ASSESSMENT

Table a. General cognitive profile

Test	**raw accuracy**
Abstraction[1]	5/6
Cognitive estimations[1]	4/5
WECHSLER MEMORY SCALE[2]: Total	62
Sub-scales	
Information	5#
Orientation	5#
Mental control	8
Logical memory	9,5
Digit span forward	8
Digit span backward	6
Visual reproduction	9
Associative memory	11,5^
Memory Quotient	97
Story Recall (long term memory)[1]	15.6/16
Visual Search[1]	44/60
Trail Making Test A[4]	35"
Trail Making Test B[4]	100"
Elithorn's Perceptual Maze Test[1]	13
Drawing copy[4]	2/2
Ideomotor apraxia[5]	6/6

[1]Spinnler and Tognoni (1987); [2] Wechsler (); [4]ENB; [5]APRAXIA; ° score at lower limits of normal performance; ^ score below 5% cut off; $ score below 25% cut off; * score below 2sd normal mean; # strongly impaired.

Table b. Visual abilities

VOSP[1] Sub-tests	**raw accuracy**
Screening test	20
1. Incomplete letters	20
2. Silhouettes	16^
3. Object decision	16
4. Progressive silhouettes	10
5. Dot counting	10
6. Position discrimination	19
7. Number location	10
8. Cube analysis	9
Embedded Figures[4]	23$

[1]Warrington, James (1991); [2]ENB; ^; $.

APPENDIX G- Naming Task sub categories' items.

Living Things

Animals: *bear, camel, cat, cow, crocodile, deer, dog, donkey, elephant, fox, frog, giraffe, goat, hedgehog, hippopotamus, horse, kangaroo, lion, monkey, mouse, pig, rabbit, rhinoceros, sheep, squirrel, tiger, turtle, zebra.*

Birds: *duck, eagle, vulture, canary, stork, swan, dove, raven, flamingo, gull, hen, cock, owl, crow, goose, parrot, sparrow, peacock, pelican, penguin, chicken, swallow, ostrich, toucan.*

Small animals and insects: *ant, beetle, bee, bug, butterfly, caterpillar, cricket, dragonfly, firefly, fly, grasshopper, ladybird, mosquito, scorpion, snail, spider, wasp, worm.*

Plants and flowers: *cactus, cyclamen, cypress, daisy, edelweiss, fir-tree, grass, ivy, mimosa, narcissus, oak, palm, poppy, rose, sunflower, tulip, violet, wheat.*

Fruits and vegetables: *apple, apricot, artichoke, banana, carrot, cauliflower, cherry, cucumber, garlic, kiwi, lemon, melon, onion, orange, peach, pear, pepper, pineapple, strawberry, tomato, watermelon.*

Non Living Things

Tools: *axe, bottle-opener, can opener, compasses, corkscrew, fork, hammer, knife, monkey wrench, nutcrackers, paintbrush, pen, pliers, rake, saw, scissors, screwdriver, shovel, spoon, toothbrush, tweezers, wrench.*

Musical instruments: *accordion, bagpipes, castanets, cello, clarinet, cymbals, drum, drums, electric guitar, flute, guitar, harmonica, harp, horn, keyboard, mandolin, organ, piano, pipe, saxophone, trombone, trumpet, violin.*

Textiles: *bathrobe, blue-jeans, carpet, doily, door-mat, drier, handkerchief, jacket, mattress, military uniform, pyjama, shirt, skirt, sockets, sponge, sponge cloth, sweater, tablecloth, tie.*

Balls (used for the following sports-games): *baseball, basketball, billiard ball, bowling, football, golf, marble, rugby, tennis, tennis table, volleyball.*

APPENDIX H- Statistical analysis (Chapter 4)

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Comparison between the Living Things' sub-categories: colour conditions Fruit&Veg-Animals: $\chi^2=.09$, *df*=1, p=.38, *n.s.*; Fruit&Veg-Birds: $\chi^2=.08$, *df*=1, p=.39, *n.s.*; Fruit&Veg-Small Animals: $\chi^2=.01$, *df*=1, p=.46, *n.s.*; Fruit&Veg-Plants: $\chi^2=.61$, *df*=1, p=.22, *n.s;* Animals-Birds: $\chi^2=.35$, *df*=1, p=.28, *n.s;* Animals-Small Animals: $\chi^2=.13$, *df*=1, p=.37, *n.s;* Animals-Plants: $\chi^2=.1.25$, *df*=1, p=.13, *n.s;* Birds-Small Animals: $\chi^2=.02$, *df*=1, p=.44, *n.s;* Birds-Plants: $\chi^2=.26$, *df*=1, p=.31, *n.s;* Small Animals-Plants: $\chi^2=.36$, *df*=1, p=.27, *n.s.* **Comparison between the Living Things' sub-categories: black and white conditions** Fruit&Veg-Animals: $\chi^2=.29$, *df*=1, p=.43, *n.s.*; Fruit&Veg-Birds: $\chi^2=1.19$, *df*=1, p=.14, *n.s.*; Fruit&Veg-Small Animals: $\chi^2=.04$, *df*=1, p=.42, *n.s.*; Fruit&Veg-Plants: $\chi^2=1.31$, *df*=1, p=.29, *n.s.*; Animals-Birds: $\chi^2=1.75$, *df*=1, p=.09, *n.s.*; Animals-Small Animals: $\chi^2=.13$, *df*=1, p=.37, *n.s.*; Animals-Plants: $\chi^2=1.78$, *df*=1, p=.11, *n.s.*; Birds-Small Animals: $\chi^2=.56$, *df*=1, p=.23, *n.s.*; Birds-Plants: $\chi^2=.05$, *df*=1, p=.42, *n.s.*; Small Animals-Plants: $\chi^2=.73$, *df*=1, p=.20, *n.s.* **Comparison between the Non Living Things' sub-categories: colour conditions** Tools-Textiles: $\chi^2=6.32$, *df*=1, p<.01; Tools-Musical Instruments: $\chi^2=18.59$, *df*=1, p<.001; Tools-Balls: $\chi^2=22.64$, *df*=1, p<.001; Textiles-Musical Instruments: $\chi^2=5.21$, *df*=1, p<.05; Textiles-Balls: $\chi^2=7.63$, *df*=1, p<.005; Musical Instruments-Balls: $\chi^2=2.09$, *df*=1, p=.07, *n.s.* **Comparison between the Non Living Things' sub-categories: black and white conditions** Tools-Textiles: $\chi^2=.44$, *df*=1, p=.27, *n.s.*; Tools-Musical Instruments: $\chi^2=3.96$, *df*=1, p<.05; Tools-Balls: $\chi^2=.21$, *df*=1, p=.33, *n.s.;* Textiles-Musical Instruments: $\chi^2=1.62$, *df*=1, p=.10, *n.s.*; Textiles-Balls: $\chi^2=5.04$, *df*=1, p<.05; Musical Instruments-Balls: $\chi^2=3.96$, *df*=1, p<.05. **Comparison between Living and Non Living Things' sub-categories: colour conditions** Tools-Fruit&Veg: $\chi^2=10.44$, *df*=1, p<.001; Tools-Animals: $\chi^2=9.42$, *df*=1, p<.001; Tools-Birds: $\chi^2=11.74$, *df*=1, p<.001; Tools-Small Animals: $\chi^2=10.31$, *df*=1, p<.005; Tools-Plants: $\chi^2=14.40$, *df*=1, p<.001; Textiles-Fruit&Veg: $\chi^2=.82$, *df*=1, p=.18, *n.s.*; Textiles-Animals: $\chi^2=.46$, *df*=1, p=.25, *n.s.*; Textiles-Birds: $\chi^2=1.33$, *df*=1, p=.12, *n.s.*; Textiles-Small Animals: $\chi^2=.79$, *df*=1, p=.20, *n.s.;* Textiles-Plants: $\chi^2=2.59$, *df*=1, p=.05; Musical Instruments-Fruit&Veg: $\chi^2=2.09$, *df*=1, p=.07, *n.s.;* Musical Instruments-Animals: $\chi^2=3.42$, *df*=1, p<.05; Musical Instruments-Birds: $\chi^2=1.30$, *df*=1, p=.13, *n.s.*; Musical Instruments-Small Animals: $\chi^2=1.37$, *df*=1, p=.12, *n.s.;* Musical Instruments-Plants: $\chi^2=.33$, *df*=1, p=.28, *n.s.*; Balls-Animals: $\chi^2=5.80$, *df*=1, p<.05; Balls-Fruit&Veg: $\chi^2=4.29$, *df*=1, p<.05*;* Balls-Birds: $\chi^2=.07$, *df*=1, p<.05; Balls-Small Animals: $\chi^2=3.32$, *df*=1, p<.05; Balls-Plants: $\chi^2=1.85$ *df*=1, p=.10, *n.s.* **Comparison between Living and Non Living Things' sub-categories: black and white conditions** Tools-Fruit&Veg: $\chi^2=1.62$, *df*=1, p=.10, *n.s.*; Tools-Animals: $\chi^2=1.39$, *df*=1, p=.12, *n.s.*; Tools-Small Animals: $\chi^2=1.74$, *df*=1, p=.11, *n.s.*; Tools-Birds: $\chi^2=5.15$, *df*=1, p<.05; Tools-Plants: $\chi^2=4.80$, *df*=1, p<.05; Textiles-Fruit&Veg: $\chi^2=.31$, *df*=1, p=.29, *n.s.*; Textiles-Animals: $\chi^2=.19$, *df*=1, p=.33, *n.s.*; Textiles-Birds: $\chi^2=2.44$, *df*=1, p=.06; Textiles-Small Animals: χ^2=.47, *df*=1, p=.26, *n.s.*; Textiles-Plants: χ^2=2.44, *df*=1, p=.07; Musical Instruments-Fruit&Veg: χ^2=.59, *df*=1, p=.22, *n.s.*; Musical Instruments-Animals: χ^2=.98, *df*=1, p=.16, *n.s.;* Musical Instruments-Birds: χ^2=.12, *df*=1, p=.37, *n.s.*; Musical Instruments-Small Animals: χ^2=.21, *df*=1, p=.32, *n.s.;* Musical Instruments-Plants: χ^2=.27, *df*=1, p=.29, *n.s.;* Balls-Fruit&Veg: χ^2=3.46, *df*=1, p<.05; Balls-Animals: χ^2=4.35, *df*=1, p<.05; Balls-Birds: χ^2=0.85 *df*=1, p=.20, *n.s.*; Balls-Small Animals: χ^2=4.29, *df*=1, p=.08; Balls-Plants: χ^2=2.25 *df*=1, p=.08.

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Comparison between the Living Things' sub-categories: colour conditions Fruit&Veg-Animals: χ^2=0.08, *df*=1, p=.40, *n.s;* Fruit&Veg-Birds: χ^2=9.58, *df*=1, p<.001; Fruit&Veg-Small Animals: χ^2=1.92, *df*=1, p=.11, *n.s.*; Fruit&Veg-Plants: χ^2=2.68, *df*=1, p=.07; Animals-Birds: χ^2=2.42, *df*=1, p=.08; Animals-Small Animals: χ^2=3.00, *df*=1, p=.07; Animals-Plants: χ^2=4.06, *df*=1, p<.05; Birds-Small Animals: χ^2=.08, *df*=1, p=.37, *n.s.*; Birds-Plants: χ^2=.23, *df*=1, p=.33, *n.s.*; Small Animals-Plants: χ^2=.03, *df*=1, p=.44, *n.s.* **Comparison between the Living Things' sub-categories: black and white conditions** Fruit&Veg-Animals: χ^2=0.04, df=1, p=.43, *n.s.*; Fruit&Veg-Birds: χ^2=2.04, df=1, p=.09, n.s.; Fruit&Veg-Small Animals: χ^2=.10, df=1, p=.39, *n.s.*; Fruit&Veg-Plants: χ^2=.35, df=1, p=.18, *n.s.*; Animals-Birds: χ^2=2.14, *df*=1, p=.08; Animals-Small Animals: χ^2=.02, df=1, p=.48, *n.s.*; Animals-Plants: χ^2=1.66, df=1, p=.13, *n.s.*; Birds-Small Animals: χ^2=1.02, *df*=1, p=.18, *n.s.*; Birds-Plants: χ^2=4.24, *df*=1, p<.05; Small Animals-Plants: χ^2=1.83, *df*=1, p=.14, *n.s.*. **Comparison between the Non Living Things' sub-categories: colour conditions** Tools-Textiles: χ^2=.003, *df*=1, p=.48, *n.s.*; Tools-Musical Instruments: χ^2=5.63, *df*=1, p<.05; Tools-Balls: χ^2=5.07, *df*=1, p<.05; Textiles-Musical Instruments: χ^2=5.21, *df*=1, p<.05; Textiles-Balls: χ^2=4.72, *df*=1, p<.05; Musical Instruments-Balls: χ^2=.23, *df*=1, p=.44, *n.s.* **Comparison between the Non Living Things' sub-categories: black and white conditions** Tools-Textiles: χ^2=.84, *df*=1, p=.22, *n.s.;* Tools-Musical Instruments: χ^2=5.83, *df*=1, p<.05; Tools-Balls: χ^2=9.82, *df*=1, p<.01; Textiles-Musical Instruments: χ^2=2.05, *df*=1, p=.09, *n.s.*; Textiles-Balls: χ^2=4.62, *df*=1, p<.05; Musical Instruments-Balls: χ^2=.97, *df*=1, p=.18, *n.s.* **Comparison between Living and Non Living Things' sub-categories: colour conditions** Tools-Fruit&Veg: χ^2=.003, *df*=1, p=.48, *n.s.*; Tools-Animals: χ^2=.11, *df*=1, p=.38, *n.s.*; Tools-Birds: χ^2=1.28, *df*=1, p=.15, *n.s.*; Tools-Small Animals: χ^2=1.74, *df*=1, p=.12, *n.s.*; Tools-Plants: χ^2=2.45, *df*=1, p=.08, *n.s.*; Textiles-Fruit&Veg: χ^2=.01, *df*=1, p=.46, *n.s.*; Textiles-Animals: χ^2=.15, *df*=1, p=.36, *n.s.*; Textiles-Birds : χ^2=.18, *df*=1, p=.17, *n.s.*; Textiles-Small Animals : χ^2=.17, *df*=1, p=.35, *n.s.*; Textiles-Plants : χ^2=2.22, *df*=1, p=.09, *n.s.;* Musical Instruments-Fruit&Veg: χ^2=6.03, *df*=1, p<.05; Musical Instruments-Animals: χ^2=8.43, *df*=1, p<.01; Musical Instruments-Birds: χ^2=1.59, *df*=1, p=.10, *n.s.;* Musical Instruments-Small Animals: χ^2=.69, *df*=1, p=.22, *n.s.*; Musical Instruments-Plants: χ^2=.49, *df*=1, p=.26, *n.s.*; Balls-Fruit&Veg: χ^2=5.43, *df*=1, p<.05; Balls-Animals: χ^2=7.53, *df*=1, p<.01; Balls-Birds:

χ^2=1.50, *df*=1, p=.13, *n.s.*; Balls-Small Animals: χ^2=.75, *df*=1, p=.22, *n.s.*; Balls-Plants: χ^2=.56, *df*=1, p=.25, *n.s.* **Comparison between Living and Non Living Things' sub-categories: black and white conditions** Tools-Fruit&Veg: χ^2=.73, *df*=1, p=.23, *n.s.*; Tools-Animals: χ^2=1.18, *df*=1, p=.15, *n.s.*; Tools-Birds: χ^2=5.37, *df*=1, p<.01; Tools-Small Animals: χ^2=1.31, *df*=1, p=.17, *n.s.*; Tools-Plants: χ^2=.49, *df*=1, p=.34, *n.s.*; Textiles-Fruit&Veg: χ^2=0, *df*=1, p=.47, *n.s.*; Textiles-Animals: χ^2=.02, *df*=1, p=.46, *n.s.*; Textiles-Birds : χ^2=1.78, *df*=1, p=.11, *n.s.*; Textiles-Small Animals : χ^2=.06, *df*=1, p=.41, *n.s.*; Textiles-Plants : χ^2=1.45, *df*=1, p=.17, *n.s.;* Musical Instruments-Fruit&Veg: χ^2=2.33, df=1, p=.08; Musical Instruments-Animals: χ^2=2.49, *df*=1, p=.07; Musical Instruments-Birds: χ^2=.01, *df*=1, p=.45, *n.s.*; Musical Instruments-Plants: χ^2=4.54, *df*=1, p<.05; Musical Instruments-Small Animals: χ^2=1.22, *df*=1, p=.15, *n.s.;* Balls-Animals: χ^2=5.53, *df*=1, p<.05; Balls-Birds: χ^2=.27, *df*=1, p=.16, *n.s.*; Balls-Small Animals: χ^2=3.35, *df*=1, p<.05; Balls-Plants: χ^2=7.47, *df*=1, p<.01.

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Comparison between the Living Things' sub-categories: colour conditions Fruit&Veg-Animals: χ^2=1.10, *df*=1, p=.15, *n.s.*; Fruit&Veg-Birds: χ^2=5.71, *df*=1, p<.01; Fruit&Veg-Small Animals: χ^2=4.64, *df*=1, p<.05; Fruit&Veg-Plants: χ^2=5.54, *df*=1, p<.01; Animals-Birds: χ^2=2.22, *df*=1, p=.07; Animals-Small Animals: χ^2=1.67, *df*=1, p=.098, *n.s.*; Animals-Plants: χ^2=2.31, *df*=1, p=.07; Birds-Small Animals: χ^2=0.05, *df*=1, p=.47, *n.s.*; Birds-Plants: χ^2=0.04, *df*=1, p=.43, *n.s.*; Small Animals-Plants: χ^2=0.06, *df*=1, p=.40, *n.s.* **Comparison between the Living Things' sub-categories: black and white conditions** Fruit&Veg-Animals: χ^2=.03, *df*=1, p=.44, *n.s.* ; Fruit&Veg-Birds: χ^2=5.53, *df*=1, p<.05; Fruit&Veg-Small Animals: χ^2=.002, *df*=1, p=.48, *n.s.*; Fruit&Veg-Plants: χ^2=5.51, *df*=1, p<.05; Animals-Birds: χ^2=3.73, *df*=1, p<.05; Animals-Small Animals: χ^2=.008, *df*=1, p=.46, *n.s.*; Animals-Plants: χ^2=4.68, *df*=1, p<.05; Birds-Small Animals: χ^2=2.95, *df*=1, p<.05; Birds-Plants: χ^2=0.31, *df*=1, p=.31, *n.s.*; Small Animals-Plants: χ^2=3.94, *df*=1, p<.05. **Comparison between the Non Living Things' sub-categories: colour conditions** Tools-Textiles: χ^2=.01, df=1, p=.46, *n.s.*; Tools-Musical Instruments: χ^2=5.18, *df*=1, p<.05; Tools-Balls: χ^2=11.83, *df*=1, p<.001; Textiles-Musical Instruments: χ^2=4.41, *df*=1, p<.05; Textiles-Balls: χ^2=10.61, *df*=1, p<.005; Musical Instruments-Balls: χ^2=2.73, *df*=1, p=.06. **Comparison between the Non Living Things' sub-categories: black and white conditions** Tools-Textiles: χ^2=.40, df=1, p=.28, *n.s.*; Tools-Musical Instruments: χ^2=5.35, *df*=1, p<.01; Tools-Balls: χ^2=12.02, *df*=1, p<.001; Textiles-Musical Instruments: χ^2=2.70, *df*=1, p<.05; Textiles-Balls: χ^2=8.24, *df*=1, p<.005; Musical Instruments-Balls: χ^2=2.69, *df*=1, p=.06. **Comparison between Living and Non Living Things' sub-categories: colour conditions** Tools-Fruit&Veg: χ^2=1.76, *df*=1, p=.11, *n.s.*; Tools-Animals: χ^2=5.51, *df*=1, p<.01; Tools-Birds: χ^2=12.78, *df*=1, p<.001; Tools-Small Animals: χ^2=11.02, *df*=1, p<.001; Tools-Plants: χ^2=12.21, *df*=1, p<.001; Textiles-Fruit&Veg: χ^2=1.39, *df*=1, p=.14, *n.s.;* Textiles-Animals: χ^2=4.71, *df*=1, p<.05; Textiles-Birds: χ^2=11.38, *df*=1, p<.001; Textiles-Small Animals: χ^2=9.79, *df*=1, p<.001;

Textiles-Plants: $\chi^2=10.91$, *df*=1, p<.001; Musical Instruments-Fruit&Veg: $\chi^2=.97$, *df*=1, p=.16, *n.s.*; Musical Instruments-Animals: $\chi^2=.003$, *df*=1, p=.48, *n.s.*; Musical Instruments-Birds: $\chi^2=2.28$, *df*=1, p=.07; Musical Instruments-Small Animals: $\chi^2=1.73$, *df*=1, p=.09, *n.s.*; Musical Instruments-Plants: $\chi^2=2.37$, *df*=1, p=.06; Balls-Fruit&Veg: $\chi^2=5.53$, *df*=1, p<.05; Balls-Animals: $\chi^2=2.67$, *df*=1, p=.06; Balls-Birds: $\chi^2=.34$, *df*=1, p=.30, *n.s.*; Balls-Small Animals: $\chi^2=.37$, *df*=1, p=.29, *n.s.*; Balls-Plants: $\chi^2=.17$, *df*=1, p=.36, *n.s.* **Comparison between Living and Non Living Things' sub-categories: black and white conditions** Tools-Fruit&Veg: $\chi^2=2.92$, *df*=1, p=.06; Tools-Animals: $\chi^2=4.06$, *df*=1, p<.05; Tools-Birds: $\chi^2=13.54$, *df*=1, p<.001; Tools-Small Animals: $\chi^2=2.86$, *df*=1, p=.06; Tools-Plants: $\chi^2=14.02$, *df*=1, p<.001; Textiles-Fruit&Veg: $\chi^2=1.15$, *df*=1, p=.16, *n.s.*; Textiles-Animals: $\chi^2=1.79$, *df*=1, p=.09; Textiles-Birds: $\chi^2=9.12$, *df*=1, p<.01; Textiles-Small Animals: $\chi^2=1.16$, *df*=1, p=.16, *n.s.*; Textiles-Plants: $\chi^2=9.79$, *df*=1, p<.001; Musical Instruments-Fruit&Veg: $\chi^2=.24$, *df*=1, p=.31, *n.s.*; Musical Instruments-Animals: $\chi^2=.14$, *df*=1, p=.35, *n.s.*; Musical Instruments-Birds: $\chi^2=2.28$, *df*=1, p=.07; Musical Instruments-Small Animals: $\chi^2=.16$, *df*=1, p=.34, *n.s.*; Musical Instruments-Plants: $\chi^2=3.30$, *df*=1, p<.05; Balls-Fruit&Veg: $\chi^2=3.74$, *df*=1, p<.05; Balls-Animals: $\chi^2=3.78$, *df*=1, p<.05; Balls-Birds: $\chi^2=.28$, *df*=1, p=.32, *n.s.*; Balls-Small Animals: $\chi^2=3.32$, *df*=1, p<.05; Balls-Plants: $\chi^2=.002$, *df*=1, p=.49, *n.s.*

SER: WORD TO PICTURE matching tasks

Comparison between the Living Things' sub-categories: colour conditions Fruit&Veg-Animals: $\chi^2=1.37$, *df*=1, p=.18, *n.s.*; Fruit&Veg-Birds: $\chi^2=6.59$, *df*=1, p<.01; Fruit&Veg-Small Animals: $\chi^2=5.89$, *df*=1, p<.05; Fruit&Veg-Plants: $\chi^2=7.85$, *df*=1, p<.005; Animals-Birds: $\chi^2=4.55$, *df*=1, p<.05; Animals-Small Animals: $\chi^2=3.56$, *df*=1, p<.05; Animals-Plants: $\chi^2=5.57$, *df*=1, p<.05; Birds-Small Animals: $\chi^2=.03$, *df*=1, p=.44, *n.s.*; Birds-Plants: $\chi^2=.16$, *df*=1, p=.35, *n.s.*; Small Animals-Plants: $\chi^2=.27$, *df*=1, p=.31, *n.s.* **Comparison between the Living Things' sub-categories: black and white conditions** Fruit&Veg-Animals: $\chi^2=1.14$, *df*=1, p=.17, *n.s.;* Fruit&Veg-Birds: $\chi^2=1.75$, *df*=1, p=.12, *n.s.*; Fruit&Veg-Small Animals: $\chi^2=3.37$, *df*=1, p=.057; Fruit&Veg-Plants: $\chi^2=.16$, *df*=1, p=.37, *n.s.;* Animals-Birds: $\chi^2=.14$, *df*=1, p=.36, *n.s.*; Animals-Small Animals: $\chi^2=98$, *df*=1, p=.18, *n.s.*; Animals-Plants: $\chi^2=.26$, *df*=1, p=.34, *n.s.;* Birds-Small Animals: $\chi^2=.33$, *df*=1, p=.30, *n.s.*; Birds-Plants: $\chi^2=.58$, *df*=1, p=.26, *n.s.*; Small Animals-Plants: $\chi^2=1.15$, *df*=1, p=.14, *n.s.* **Comparison between the Non Living Things' sub-categories: colour conditions** Tools-Textiles: $\chi^2=1.08$, *df*=1, p=.24, *n.s.*; Tools-Musical Instruments: $\chi^2=7.46$, *df*=1, p<.005; Tools-Balls: $\chi^2=11.67$, *df*=1, p<.005; Textiles-Musical Instruments: $\chi^2=4.38$, *df*=1, p<.05; Textiles-Balls: $\chi^2=7.47$, *df*=1, p<.01; Musical Instruments-Balls: $\chi^2=.82$, *df*=1, p=.20, *n.s.* **Comparison between the Non Living Things' sub-categories: black and white conditions** Tools-Textiles: $\chi^2=0.73$, *df*=1, p=23, *n.s.*; Tools-Musical Instruments: $\chi^2=7.42$, *df*=1, p<.005; Tools-Balls: $\chi^2=17.17$, *df*=1, p<.001; Textiles-Musical Instruments: $\chi^2=3.35$, *df*=1, p<.05; Textiles-Balls: $\chi^2=10.65$, *df*=1, p<.005; Musical Instruments-Balls: $\chi^2=3.55$, *df*=1, p<.05

Comparison between Living and Non Living Things' sub-categories: colour conditions Tools-Fruit&Veg: $\chi^2=0$, *df*=1, $p=.46$, *n.s*; Tools-Animals: $\chi^2=1.61$, *df*=1, $p=.16$, *n.s.*; Tools-Birds: $\chi^2=7.64$, *df*=1, $p<.005$; Tools-Small Animals: $\chi^2=6.80$, *df*=1, $p<.01$; Tools-Plants: $\chi^2=9.07$, *df*=1, $p<.005$; Textiles-Fruit&Veg: $\chi^2=.92$, *df*=1, $p=.26$, *n.s*; Textiles-Animals : $\chi^2=.10$, *df*=1, $p=.40$, *n.s.*; Textiles-Birds: $\chi^2=4.58$, *df*=1, $p<.05$; Textiles-Small Animals: $\chi^2=1.18$, *df*=1, $p=.16$, *n.s.;* Textiles-Plants: $\chi^2=5.58$, *df*=1, $p<.05$; Musical Instruments-Fruit&Veg: $\chi^2=8.68$, *df*=1, $p<.005$; Musical Instruments-Animals: $\chi^2=3.55$, *df*=1, $p<.05$; Musical Instruments-Birds: $\chi^2=.0003$, *df*=1, $p=.49$, *n.s.*; Musical Instruments-Small Animals: $\chi^2=.02$, *df*=1, $p=.44$, *n.s.*; Musical Instruments-Plants: =0.16, *df*=1, $p=.35$, *n.s.*; Balls-Fruit&Veg: $\chi^2=18.09$, *df*=1, $p<.001$; Balls-Animals: $\chi^2=12.08$, *df*=1, $p<.001$; Balls-Birds: $\chi^2=.83$, *df*=1, $p=.20$, *n.s.*; Balls-Small Animals: $\chi^2=1.00$, *df*=1, $p=.18$, *n.s.*; Balls-Plants: $\chi^2=.27$, *df*=1, $p=.32$, *n.s.* **Comparison between Living and Non Living Things' sub-categories: black and white conditions** Tools-Fruit&Veg: $\chi^2=.83$, *df*=1, $p=.28$, *n.s.*; Tools-Animals: $\chi^2=1.38$, *df*=1, $p=.14$, *n.s.*; Tools-Birds: $\chi^2=2.06$, *df*=1, $p=.10$, *n.s.*; Tools-Small Animals: $\chi^2=3.84$, *df*=1, $p<.05$; Tools-Plants: $\chi^2=.23$, *df*=1, $p=.34$, *n.s.*; Textiles-Fruit&Veg: $\chi^2=.58$, *df*=1, $p=.26$, *n.s.*; Textiles-Animals : $\chi^2=.07$, *df*=1, $p=.41$, *n.s.*; Textiles-Birds: $\chi^2=.32$, *df*=1, $p=.31$, *n.s.*; Textiles-Small Animals: $\chi^2=1.21$, *df*=1, $p=.16$, *n.s.*; Textiles-Plants: $\chi^2=.08$, *df*=1, $p=.42$, *n.s.*; Musical Instruments-Fruit&Veg: $\chi^2=6.44$, *df*=1, $p<.01$; Musical Instruments-Animals: $\chi^2=4.28$, *df*=1, $p<.05$; Musical Instruments-Birds: $\chi^2=1.59$, *df*=1, $p=.12$, *n.s.*; Musical Instruments-Small Animals: $\chi^2=.29$, *df*=1, $p=.31$, *n.s.*; Musical Instruments-Plants $\chi^2=3.29$, *df*=1, $p<.05$; Balls-Fruit&Veg: $\chi^2=10.12$, *df*=1, $p<.005$; Balls-Animals: $\chi^2=7.53$, *df*=1, $p<.01$; Balls-Birds: $\chi^2=7.73$, *df*=1, $p<.005$; Balls-Small Animals: $\chi^2=4.34$, *df*=1, $p<.05$; Balls-Plants: $\chi^2=9.73$, *df*=1, $p<.005$