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OBJECT DECISION: THE INTERACTION OF SEMANTIC INFORMATION AND STRUCTURAL DESCRIPTION SYSTEM

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ABSTRACT

In the neuropsychological literature, visual object recognition is deemed to be subserved by structural information that is functionally independent from semantic memory. According to this view, the perceptual representation of the stimulus is compared with representations of objects previously seen and stored in the so-called “Structural Description System”, or SDS; when matching between representations occurs, the corresponding conceptual knowledge is activated. Recently, the functional independence of SDS has been challenged based on the evidence that patients affected by Semantic Dementia, a neurodegenerative condition characterized by a selective disruption of semantic memory with sparing of the early stages of visual processing, are impaired at Object Decision tasks. In the present dissertation, we aimed at investigating whether object recognition could be achieved on the basis of structural features alone, or whether semantic knowledge about the object is also involved. To this aim we created two different Object Decision tasks and administered them to healthy young subjects, elderly normal controls and neurodegenerative patients. Our findings suggest that conceptual knowledge plays a crucial role in visual object recognition, and that semantic memory and the SDS are highly interactive.

CHAPTER 1

THEORETICAL OVERVIEW

1.1 OBJECT RECOGNITION

Visual object recognition is experienced as an automatic, easy and effortless process. In fact, the operations and structures involved in visual identification are subtle and complex. Despite the constantly changing nature of visual information, we are able to recognize every single object included in a complex scene without difficulties.

From a neuropsychological perspective, it is now well established that recognition of three-dimensional objects is not a unitary activity; as a matter of fact object recognition requires the involvement of perceptual abilities, conceptual information and the interaction between perception and concepts.

In the initial stages of visual processing, different parts of the brain deal with different basic visual properties of objects in a relatively modular way: subjects start to perceive the edges of a stimulus, its length, size, color and orientation. He/she then has to discriminate it from the background, by correctly grouping its different parts together. Subsequently an invariant representation of the object is developed, that allows to recognize the stimulus from virtually *any* viewpoint (Humphreys & Riddoch, 1987). At this point, access to the general information stored about the object (structure, conceptual knowledge, name and so on) may occur.

1.1.1 Pattern Recognition

In everyday life we are able to recognize a two-dimensional pattern, such as a letter or a number, in a rapid and accurate way despite its considerable variations in size, font, color and so on. Three major theories have tried to provide an explanation for this phenomenon. At a very general level, a concept common to all these theories is that actual recognition takes place when the current visual stimulus matches objects that have been previously encountered and are stored in memory.

Template theories

The central idea behind these theories is that a miniature copy, or "template", of each of the visual patterns we know of a given object would be stored in our long-term memory. A pattern is recognized on the basis of which template offers the best match to the item. Despite having the advantage of being attractively simple, the main limitation of this theory is that it is ill-equipped to account for the ability to recognize stimuli characterized by an enormous intra-category variability (for example, we are able to recognize a dog independently from the angle from which it is observed and despite its variability in color, size, and so on).

Feature theories (Neisser, 1967)

According to this theory, a pattern consists of a set of specific features or attributes. The first step of the recognition process would consist in the extraction of the single features, which are then separately compared with information stored in memory. This theoretical approach has the advantage to overcome the limitations of the Template theories: the pattern may vary greatly in size, orientation, etc. but still be identified. On the other hand, the weakness of this theory is that it doesn't consider the relationship among the features: for instance, the features extracted from letter "A" are the same as symbols \ / -; the correct identification of the letter requires taking into consideration the relationship among such 'features'. Moreover, the fact that a subject can generally recognize three-dimensional objects also when one or more features are hidden from cannot easily be accounted for by a theory that greatly emphasizes the role of features in recognition.

Structural Description theory (Sutherland, 1973; Bruce and Green, 1990)

Structural descriptions consist of propositions, which are defined as the smallest units to which we can assign a meaning. This concept represents an advance with respect to the theories mentioned above, since "such propositions describe the nature of the components of a configuration and make explicit the structural arrangement of these parts" (Bruce & Green, 1990). The plus point of this theory is that it focuses on key aspects of stimuli. For instance, the structural description of a capital letter "T" is composed by the following propositions: (i) there are two parts, (ii) one part is a horizontal line, (iii) one part is a vertical line, (iv) the vertical line sustains the horizontal line and (v) the vertical line bisects the horizontal line. This description does not include propositions referring to the length of the lines: this allows the observer to recognize the stimulus despite variations of its constituents.

Albeit the Structural description theory contributes to the understanding of pattern recognition more than Templates and Feature theories, it is still unclear *how* information extracted from the stimulus is matched with the structural descriptions stored in memory.

The idea of a system dedicated to the analysis of parts of the objects and the relationship among them has given rise to a huge number of cognitive models, called "Structural Description Models".

In the last thirty years, this research field has represented a fertile ground for clinical and instrumental investigations and has generated various theoretical models, which have sometimes raised intriguing controversies.

Moreover, neuropsychological and neurological data from brain-damaged patients have provided an important source of evidence on the cerebral organization of object processing and its relationship with semantic memory. For example, patients with a disproportionate semantic impairment for one category of objects, or patients affected by optic aphasia, have been extremely helpful for the development of cognitive models of object recognition

In the following, I will examine the most influential theories about the relationship between object recognition and semantic memory and review the most significant case studies.

However, before starting to examine this issue, it is necessary to introduce the cognitive model that more than any other has influenced this research line, that is the one proposed by Marr in 1982 (Marr, 1982).

1.1.2 Marr's Model of Object Recognition

According to Marr's computational theory the vision process produces a series of descriptions, which contribute to a progressively more detailed representation of the visual stimulus.

He distinguished three major levels of representations (see Figure 1.1):

- *Primal sketch*: this representation provides explicit important information about the two-dimensional image, primarily the light intensity changes and their geometrical location and organization; it also includes descriptions about edges, contours and blobs.
- *2 1/2-D sketch*: this representation incorporates the depth and orientation of visible surfaces, by using information provided by shading, texture motion, binocular disparity and so on.

- *3-D model representation*: this representation describes three-dimensionally the shapes of objects.

The first two steps provide a poor basis for identifying an object, mainly because they are observer-centered, which means that they will vary greatly on the basis of the angle perspective from which the object is observed. That's why it is important for the subject to create a 3-D representation, which does not have these limitations and contains observer-independent information. According to Marr, it is at this level that the matching between the visual stimulus and the stored object representations occurs, and the stimulus can be recognized as familiar.

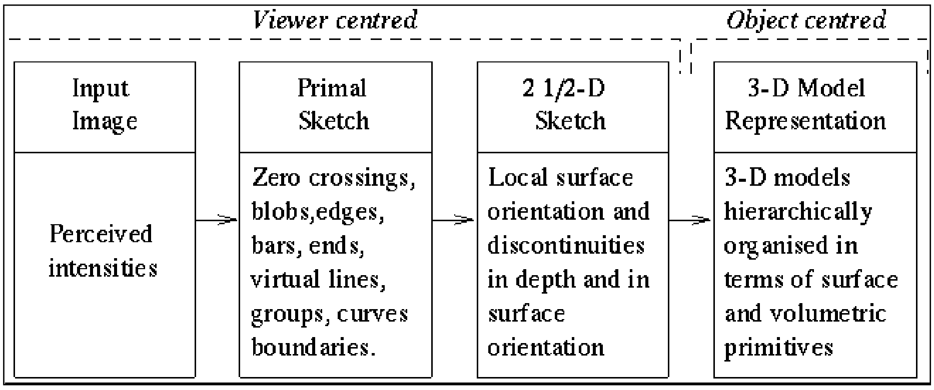


Fig. 1.1 An illustration of Marr's model of Object Recognition (from Marr, 1982).

This model also allows to make some predictions on the patient's performance, according to the stage of damage.

Imagine a patient who finds it difficult to build a *2 1/2-D sketch,* but can still produce the *primal sketch.* We can expect him/her to show a severe shape-processing impairment and to be unable to copy figures, despite being able to carry on some basic perceptual processes and to identify objects only on the basis of sense modalities other than the visual one.

On the other hand, brain-damaged patients who cannot readily turn the *2 1/2-D sketch* into a *3-D model representation* are able to copy figures in a quite accurate way, and to recognize objects presented in the most typical angle (when the *2 1/2-D sketch* closely resembles the

3-D representation); however, they find great difficulty in recognizing objects presented in unusual angles.

In 1978 Warrington & Taylor studied a series of patients with right posterior injuries, who performed poorly in a task in which they were asked to decide whether two photographs of objects taken from an unusual and an usual view depicted the same object. According to Marr's theory, these findings are plausibly explained by assuming that the patients found it difficult to produce a *3-D model representation* of the visual stimuli.

1.2 OVERVIEW OF THE CURRENT THEORIES OF SEMANTIC MEMORY AND OBJECT RECOGNITION

1.2.1 The Multiple Semantics Assumption

As already mentioned, patients with recognition deficits restricted to a single category of objects have often provided crucial contribution to the understanding of normal functioning of the human brain.

Although anecdotal reports of patients with category-specific impairments date back to 1946 (Nielsen, 1946), the first detailed study was published in 1984, when Elizabeth Warrington and Tim Shallice examined four patients with bilateral temporal lobe damage due to Herpes Simplex Virus Encephalitis (HSVE) (Warrington & Shallice, 1984). They all exhibited a selective deficit in recognizing living things (animals, fruits and vegetables), compared to a relatively spared knowledge for inanimate objects (furniture, tools and clothing). Four assessment methods were used: verbal descriptions, confrontation naming, mimed responses and picture-to-word matching. Among these four patients, J.B.R. was studied in more detail. In summary, his deficit for living items was surely semantic in nature. His difficulty in naming living things was not the result of a deficit at a "low-level" perceptual processing, since he performed within the normal range in a task in which matching between objects presented in usual and unusual views was requested. Moreover, he was unable to access information about living things through other modalities (for example, verbal descriptions). However, J.B.R. was also impaired in recognizing some non-living categories such as food, musical instruments and clothes. Warrington and Shallice concluded that the selective deficits of J.B.R. did not reflect the impairment of a system specific for the recognition of living things; instead, they suggested that category-specificity may emerge from a difference in the type of information needed to recognize different categories of objects. In particular, they proposed two functionally independent semantic systems: one for sensory information (such as color, shape, size), which is crucial in differentiating living things, and the other for functional information (e.g. how objects are used), which is more relevant in differentiating non-living things. To account for J.B.R.'s poor performance with food, clothes and musical instruments, they argued that "*these categories have only a generic function, and that such stimuli might be more easily differentiated by their sensory features*" (Warrington & Shallice, 1984).

This theory is known as the **Sensory/Functional model**: the dissociation between impaired and spared categories is related to the degree of sensory and functional knowledge necessary for their respective identification.

Some years later, Warrington and McCarthy modified the sensory/functional distinction turning it into the **Multiple Processing Channels Account** (Warrington & McCarthy, 1987; Crutch & Warrington, 2003), where specialized motor and sensory channels store information acquired through a particular modality. In the authors' opinion, there might be different types of semantic knowledge (visual, verbal, auditory, tactile, encyclopedic, etc.) and the representation of an object would be the sum of the activity across all these multiple representations (see Figure 1.2 for a graphic illustration of the model). This theory leads to the prediction that patients with poor identification of living things will be disproportionately impaired at retrieving visual knowledge about those items.

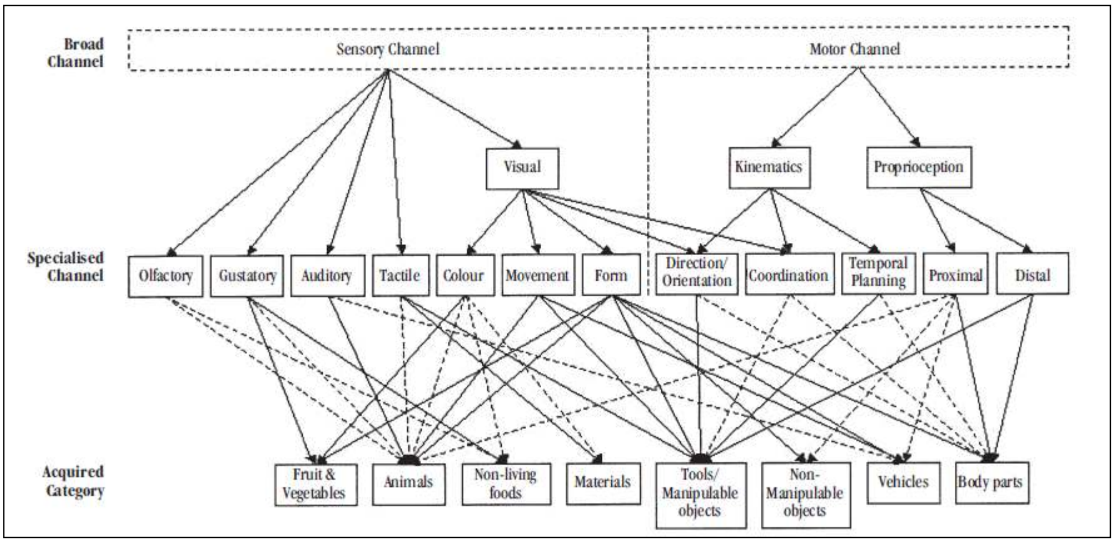


Fig. 1.2 An illustration of the Multiple processing channels account (from Crutch & Warrington, 2003).

To summarize, the accounts described above, hypothesize a subdomain of semantic memory devoted to the analysis and recognition of visual features of stimuli, called visual semantics. According to the authors, the visual semantic system would include not only information about the structure, shape and size of the object, but also about visual associations between objects (e.g. the visual association between a bee and a flower).

1.2.2 The Pre-Semantic Accounts for Object Recognition

In contrast with the theories discussed in the previous paragraph, the idea of a specific domain of conceptual knowledge that is dedicated to analyze and recognize objects presented through the visual channel (visual semantic) has been questioned by other research groups.

This research line has been heavily influenced by Marr, who argues that object recognition does not require access to the semantic system (i.e. a visual stimulus is recognized before its meaning is retrieved). This claim is based essentially on reports of patients who are impaired at accessing semantic knowledge from vision, but are able to perform well in an object decision task (Riddoch & Humphreys, 1987; Stewart et al., 1992; Sheridan & Humphreys, 1993; Hillis & Caramazza, 1995).

For example, Riddoch & Humphreys (1987) and Hillis & Caramazza (1995) presented two seminal studies of patients J.B. and D.H.Y, respectively, who suffered from optic aphasia. This neuropsychological condition appears to be very useful to investigate the relationship between object processing and conceptual knowledge, being a naming disorder specific to a single modality of input (more frequently vision) in the absence of semantic memory impairment.

J.B. performed within the normal range when asked to decide whether line drawings represented real or chimeric stimuli, but he found it difficult to link semantic knowledge to visual stimuli, for instance when he had to decide which two of three objects were used together (but he performed flawlessly when the names of the objects were given). Humpreys and Riddoch (Riddoch & Humphreys, 1987; Humphreys et al., 1999) inferred that J.B, (i) had intact semantic memory, but could not access it from the visual route, and (ii) had access to the stored visual representations (he could perform well on the object decision task), but such representations were dissociated from semantic memory.

Data obtained from brain-damaged patients, such as J.B., led Humphreys and colleagues to postulate a multi-stage model of object recognition, which consists of six separate stages (Riddoch & Humphreys, 1993):

1. early visual processing, such as the analysis of color, size, orientation, location and length;
2. integration of the visual elements into a global shape, and segmentation of the figure from the contextual background;

3. encoding of properties of objects that remain invariant across changes of viewing angle (object constancy);

4. matching of the episodic visual representation of a stimulus with object representations stored in memory (Structural Description System). Putatively, this store should contain the structural representations of all objects that we have previously seen;

5. access to semantic memory from vision. This leads to an activation of functional characteristics and conceptual properties of the object;

6. retrieval of the object name.

Since this model is based on the assumption that visual processing is organized in a relatively modular form, it follows that brain-damaged patients whose object recognition abilities are impaired should show different patterns of performance depending on which part of the model is damaged. A schematic framework showing stages of object processing is given in Figure 1.3.

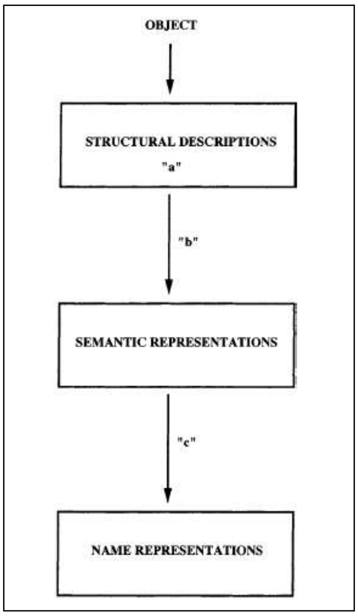


Fig. 1.3 From Humphreys et al., 1997.

The second case has been described by Caramazza et al. in 1995.

D.H.Y. had a pathological performance in naming pictures, while naming to description or tactile exploration was preserved. Moreover, she was not impaired on tasks evaluating low-level perception, such as matching identical shapes. Similarly, access to stored structural descriptions of objects was preserved, as the patient could match objects depicted from different views or perform an object decision task. These results lead the authors to claim that D.H.Y.'s impairment is to be placed after successful access to a stored representation of the stimulus structure. However, in tasks that required more detailed semantic information, the patient was far less accurate, showing that she could not retrieve the complete conceptual representations of objects. According to the authors, these results gave further evidence to the fact that object recognition can occur even in the absence of complete access to semantic memory (Hillis & Caramazza, 1995; see Figure 1.4 for a graphic illustration of the model of object recognition proposed by the authors).

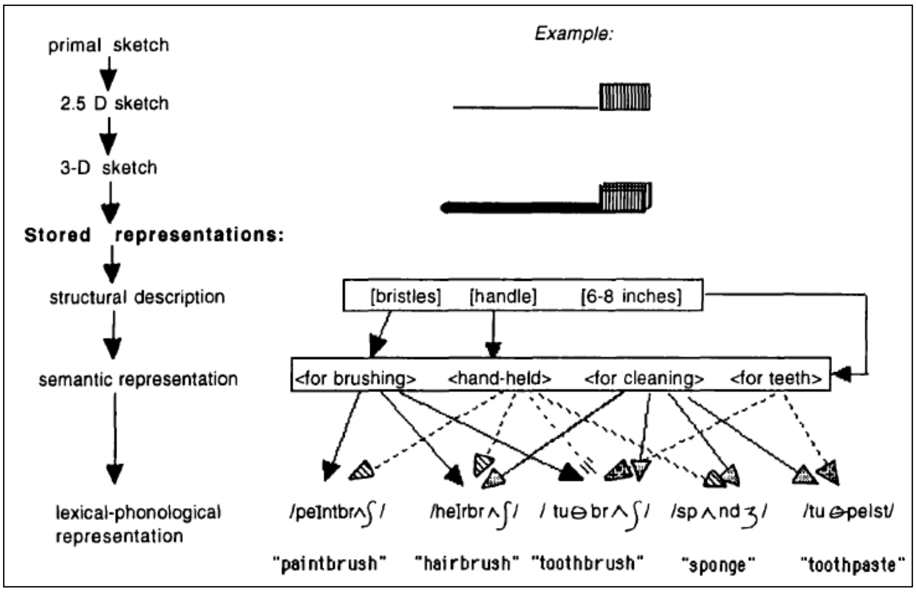


Fig. 1.4 A schematic representation of a model of visual object naming (from Hillis & Caramazza, 1995).

Thus, what emerges from these single-case studies is that poor object naming cannot be attributed to a general deficit in semantic knowledge, but rather to impaired visual access to general semantic knowledge following intact access to stored visual knowledge. These patients suggest the existence of a system (the SDS) supporting long-term structural visual knowledge about objects that does not depend on intact communication with the semantic memory. Object recognition must therefore be subserved by an independent recognition system.

As an account for the optic aphasic patients' performance, Caramazza and colleagues initially proposed the **Organized Unitary Content Hypothesis** (OUCH; Caramazza et al., 1990), arguing that there are privileged relationships between certain types of input representations (e.g. visual inputs) and certain types of output representations (e.g. knowledge of object manipulation). This would explain why optic aphasics may show intact gesturing while being impaired in naming them (Mahon & Caramazza, 2009). This theory relies on a unitary, amodal account of the semantic system, contrasting with the Multiple Semantics Assumption proposed by Warrington, Shallice and co-workers.

Besides Humphrey's and Caramazza's research groups, other authors supported this view. Coslett & Saffran, for example, developed a model of visual processing "*that can serve as a framework for the investigation and interpretation of the visual disturbances that result from brain lesion in man*" (Coslett & Saffran, 1992). Briefly, they postulate that after creating the "visual features maps", the observer produces a "Visual Analog Representation", or VAR, in which the integration of information takes place; after that, the "structural description system" is activated and allows the subject to recognize the stimulus as familiar. Semantic information will be activated only in a later stage.

Moreover, Stephen M. Kosslyn and colleagues (Kosslyn et al., 1990) proposed an ambitious theory of high-level vision by using a computer simulation model. Resuming the dichotomy of the dorsal/ventral pathways identified by Ungerleider and Mishkin (1982), the authors assume that the encoding of object information (such as shape, color, etc.) and spatial information (such as location and size) occurs in separate sub-systems, localized in the inferior temporal lobe and in the parietal lobe, respectively. In summary, in order to identify an object, its image must be projected into the visual buffer, where the attention window decides which information is to be sent to the dorsal stream and to the ventral stream for further processing. Object properties are processed in the ventral stream. The pre-processing subsystem uses shape, color and texture to extract "*trigger features*". These features are then matched against those of previously encoded objects in the "*pattern activation sub-system*" (the so called "Structural Description System" in the cognitive models previously described). If the matching fully occurs, the output from the ventral stream may be sufficient for a unique identification in the associative memory. A graphic illustration of the sub-systems posited by the authors is given in Figure 1.5.

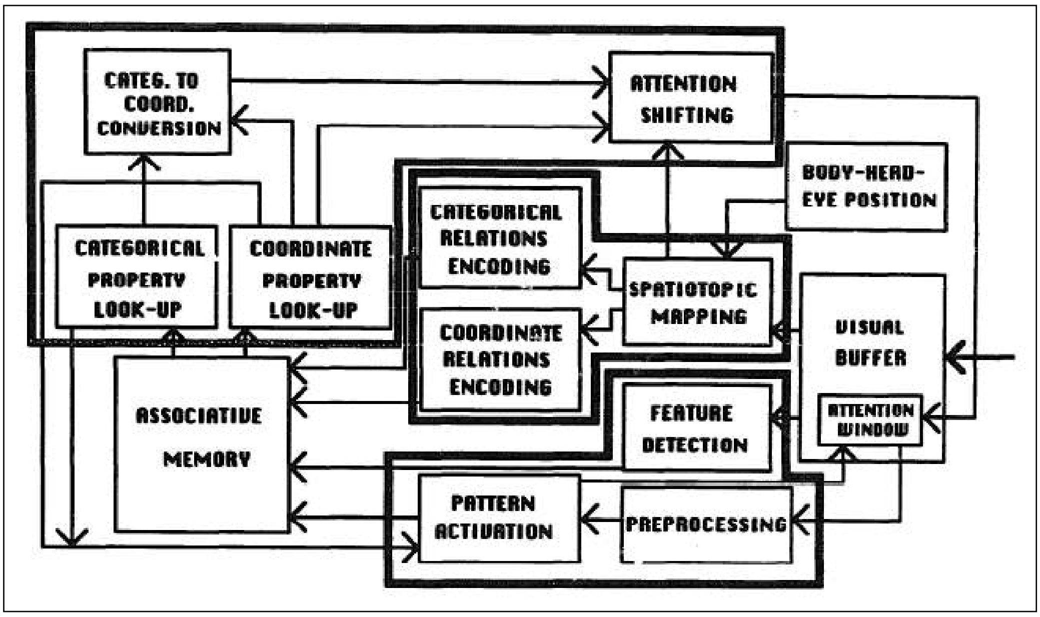


Fig. 1.5 From Kosslyn et al., 1990.

More recently, a Danish research group (Gerlach et al., 2009) has proposed a new model of visual object recognition, on the basis of functional imaging data obtained on healthy subjects: the PACE model (Pre-semantic Account of Category-Effects). This model assumes two processing stages: i) *shape configuration* (the binding of shape elements into an elaborate shape description) and ii) *selection* (among competing representations in visual long-term memory, i.e. the SDS). The basic assumption is that processing is differentially affected by the structural similarity between objects in that shape descriptions of objects belonging to structurally similar categories (natural objects) are more easily configured than shape descriptions of objects belonging to structurally dissimilar categories (artefacts) whereas structurally similar objects are more difficult to match with representations stored in visual than structurally dissimilar objects (the selection stage). In summary, natural objects will be more easily configured, but matching them with the stored representations will be more difficult.

Gerlach et al.'s behavioral and functional data confirm this hypothesis, since participants took longer to recognize natural objects than artefacts in a difficult object decision task (requiring a high degree of shape selection). Functional imaging results are consistent with these data: an increased activation for natural objects with respect to artifacts was found in the anterior cingulate gyri, the left cerebellum and, in particular, in the right inferior frontal gyrus, an area which has been associated with selection among competing alternatives stored in long-term memories (Thompson-Schill, 2003).

In addition to this, compared with the baseline, object decision tasks were associated with extensive bilateral activation of the posterior and ventral parts of the brain, as well as of the frontal cortex.

According to the authors, the lack of activation in the anterior and lateral parts on the temporal lobes (areas typically involved in semantic memory) proved that object decision is based on pre-semantic structural processing.

1.2.3 An Intermediate Position: Hierarchical Knowledge and Interactive Processing

In 1988 Sartori and Job described the case of Michelangelo, a patient who presented with a category-specific impairment following HSVE. Besides a deficit in naming living entities, he was also impaired in retrieving visual information about them. Moreover, there was a deficit in an object decision task, where discrimination between real and unreal objects was requested: his performance was poorer when he had to discriminate between real and unreal animals. He was able to retrieve the correct shape of prototypical animals, but he experienced difficulties in accessing the correct shape or the correct location of the parts for low frequency animals. The conceptual knowledge of Michelangelo, however, appeared to be intact, since he could give information about animals' ferocity, noise, size, and so on. On the basis of this clinical case, Sartori and Job postulated the presence of a Structural Description System (SDS) where the visual information about the shape and about the relationship among object constituents is stored. According to their model, the SDS has two fundamental characteristics: i) the SDS and Semantic Memory are constantly connected (i.e. visual information is constantly available for the conceptual level and vice-versa) and ii) the SDS is hierarchically organized. At the top of the hierarchy we find descriptions corresponding to general category exemplars; these descriptions would become more and more detailed further down the hierarchy, at a subordinate level. In the authors' opinion, patients that present with category-specific impairments for living things may have a deficit at the lowest (most detailed) level of the structural hierarchy. They also argue that living things are usually more affected because they have "deeper" representations, with respect to artifacts (Sartori et al., 1993).

In 2001 Humphreys & Forde proposed a "Hierarchical Interactive Theory" or HIT for object recognition and naming, that adopts the architecture of the Cascade model (Humphreys et al., 1988), that is: i) a hierarchy of stored representations (structural descriptions, functional and inter-object associative information or semantic knowledge and name representations) and ii) the assumption that partial activation could be transmitted between processing systems.

According to the HIT model (see Fig. 1.6), a selective damage can occur to each form of representations so, for example, one could find a patient that shows a deficit at the level of semantic knowledge without necessarily having a deficit in stored structural representations.

Finally, although a hierarchy of memory stages is assumed, the authors stress that only the first pass of activation is hierarchical, while the processing after this pass does not have this characteristic. For example, there may be a delay in accessing the structural knowledge of an object, though access to semantic knowledge may be completed.

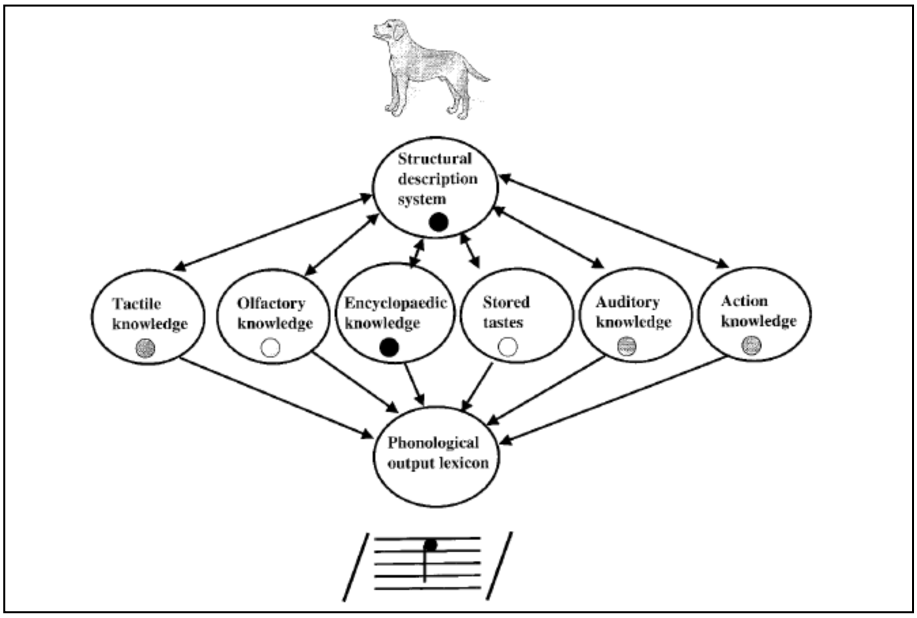


Fig. 1.6 A framework for HIT (Humphreys & Forde, 2001)

In summary, very different theoretical models of semantic memory have been proposed. The most striking controversy is between, on one hand, authors that postulate the existence of a multiple-processing-channels view of semantic memory (Warrington and colleagues) or of a highly interconnected multimodal network (Shallice and associates) and, on the other hand, authors that assume that semantic memory is a unitary amodal system (mainly Caramazza's research group).

Within this debate, it is important to note that the SDS, that is the locus where object recognition should occur, assumes very different roles. In models based on the idea of a unitary amodal semantic system, the SDS is described as an isolated system that is devoted to the matching of visual input with representations of previously known objects, and which is functionally independent from the semantic system. According to this approach, an object can be recognized as familiar without entailing access to conceptual knowledge.

The position of authors that support the idea of multiple specialized semantic systems remains more controversial, since they do not distinguish between content-bearing semantic representations and content-free structural representations, but emphasize that semantic memory serves a particular function, that is the association in memory of modality-specific perceptual representations. However, it remains unclear if they also hypothesize the existence of an SDS for the analysis of the shape of visual stimuli, or if this system is collapsed into the concept of Visual Semantics. Nevertheless, it is clear that, according to them, the ability to recognize objects from vision always draws upon semantic resources.

An intermediate position is held by those models that suggest that the SDS is hierarchically organized and constantly interacting with the semantic system (Sartori et al., 1993; Humphreys & Forde, 2001).

1.3 GENERAL AIM AND STRUCTURE OF THE DISSERTATION

The general aim of the studies that will be presented in the next chapters was to try to answer to the following question: can object recognition be achieved on the basis of structural features alone, or is semantic knowledge about the object also involved?

In Chapter 2 we present a novel object decision task, in which we manipulated the visual and semantic characteristics of stimuli with the purpose to identify the variables that can affect reality judgments. Behavioral data obtained from a group of young healthy controls are reported.

In Chapter 3 we describe a clinical study in which the task has been administered to patients affected by degenerative brain disorders impairing visuo-perceptual or semantic functions.

Finally, in Chapter 4 we applied a masked priming paradigm to a different object decision task, in order to investigate the very early stages of object recognition in healthy individuals. Performance at this experiment was also compared with that obtained by the same subjects in a parallel lexical decision task using the names of the same set of objects.

CHAPTER 2

EVALUATING THE RELATIONSHIP BETWEEN THE STRUCTURAL DESCRIPTION SYSTEM AND SEMANTIC MEMORY WITH A NEW OBJECT DECISION TASK

2.1 INTRODUCTION

The Structural Description System (SDS) can be defined as the system where the perceived visual features of stimuli are compared with the stored visual representation of known objects. If match occurs, the object can be recognized as real or familiar.

The Object Decision (OD) task, in which participants have to decide whether a picture represents a real or an unreal object, is considered a good test for the integrity of the SDS. This task was initially proposed by Judith F. Kroll and Mary C. Potter (1984) to address the question about whether pictures and words access a common conceptual representation. They developed a task analogous to the lexical decision task, creating a set of pictures of pseudo-objects and mixing them with drawings of real objects.

Riddoch & Humphreys (1987a, 1987b) introduced the OD task in the clinical setting for investigating object recognition in focal brain-damaged patients. Their OD task, included in the Birmingham Object Recognition Battery (BORB; Riddoch & Humphreys, 1993), is composed of pictures of real objects intermingled with chimeric objects. The participant has to accept the real objects and reject the chimeras. Over the years, many other OD tasks were proposed (Warrington & James, 1991; Lloyd-Jones & Humphreys, 1997; Barbarotto et al., 2002; Rogers et al., 2003; Magniè et al., 2003; Zannino et al., 2011).

Since the seminal studies by Riddoch & Humphreys (1987a, 1987b), a debate has been taking place in the neuropsychological literature, over whether the SDS is a pre-semantic independent store, or is connected to the semantic system or even integral to it.

The finding that some patients affected by visual agnosia or optic aphasia are still able to distinguish between real and unreal pictures, but are unable to access semantic information from vision, supports the conclusion that visual object recognition does not depend upon intact communication with semantics and must therefore be subserved by an independent recognition system (i.e. the SDS) (Riddoch & Humphreys, 1987; Sheridan & Humphreys, 1993; Hillis & Caramazza, 1995) (see Chapter 1 for a detailed review). This view is also supported by several neuroimaging studies, where the performance at the OD task correlates with the activation of the fusiform gyri bilaterally, while the anterior parts of the temporal lobes, which are typically involved in semantic processing, are not activated (Gerlach et al., 1999, 2006, 2007, 2009; Kellenbach et al., 2005).

However, the independence of the SDS from semantic memory was recently challenged by the observation that patients suffering from Semantic Dementia (SD) are impaired at object decision (Rogers et al., 2003; Patterson et al., 2006, 2007), and they also show high correlation between OD scores and scores on semantic tasks.

Moreover, Warrington and James (1991a) questioned the idea that the OD task proposed by Humphreys & Riddoch is a reliable and pure measure of spared SDS, positing that: "*if each part alone of a composite figure can be identified as the particular part of the object (say a cat's head or a dog's body), then the object decision task could be solved verbally or by access to visual semantic knowledge without recourse to structural knowledge of the whole. Consequently failure on such task might be more appropriately attributed to impaired visual semantic knowledge than to damaged structural description of the object*" (pag. 382).

The Authors thus proposed a new OD task that they included in the Visual Object and Space Perception battery (VOSP), and which was thought to be a more valid measure of structural knowledge: a forced-choice among four alternatives, in which a rotated two-dimensional silhouette of a real object is presented with three distractor silhouettes of imaginary objects.

Hovius and colleagues (2003) substantially agree with Warrington and James' position, claiming that the OD task does not rely on a single cognitive subsystem, and that both vision and semantics are necessary to solve the task.

Rogers and colleagues (2003) propose a theoretical stance that is in keeping with Hovius et al's hypothesis, since, according to them, reality judgments require both complex visual processing and some degree of conceptual knowledge; by manipulating the nature of the stimulus materials, one can vary the degree to which an OD task burdens semantic memory.

Recently, Zannino et al. (2011) tried to disentangle this issue, proposing that the classical OD task can be solved relying on different strategies: a "semantic strategy" and a "purely visual strategy". According to these Authors, the default strategy is the semantic one, except when there's a *disconnection* between semantic memory and vision, in which case the visual strategy may emerge. This would explain why SD patients show poor performance, while agnosic patients do not, as they may rely on their spared SDS.

The studies described above have been carried out on neuropsychological samples, while only few reports on healthy controls can be found.

So, the following question arises: what happens in the healthy brain during a reality decision task?

2.1.1 The Performance of Healthy Subjects at the Object Decision Task

Behavioral findings

Kroll & Potter (1984) obtained faster reaction times (RTs) with real objects compared to unreal stimuli. In their experiment, no distinction between natural and man-made objects was made, and unreal stimuli belonged to the set of non-objects created by the Authors.

Gerlach and colleagues, in a series of experiments, compared an easy version of the OD task, where the demand on structural differentiation is low (real items mixed with Kroll & Potter pictures), with a more difficult one (real items mixed with chimeric objects). In the difficult condition, RTs for real items were slower with respect to RTs for real items in the easy condition; moreover, RTs were slower with natural objects with respect to artifacts (Gerlach et al., 1999). No differences were found in accuracy. These findings replicated those obtained by Lloyd-Jones & Humphreys (1997) when only real items and chimeras were employed.

In 2003, Magnié and colleagues mixed real pictures, Kroll & Potter pictures and chimeras. They found a significant effect of picture type: RTs were shortest for non-objects, intermediate for objects and longest for chimeric objects, while the error rate was lower for Kroll & Potter pictures than for real and chimeric objects. They also found an effect of manipulability, with RTs for strongly manipulable objects being significantly shorter than for unmanipulable objects.

In some other studies OD has been compared with other types of tasks investigating object processing (Lloyd-Jones & Humphreys, 1997; Starrfelt & Gerlach, 2007).

Lloyd-Jones and Humphreys (1997), for example, administered a picture naming task and an OD task to the same healthy sample. Real stimuli were divided into structurally similar (fruit and vegetables) and structurally dissimilar (clothing and furniture). In the OD task these sets of stimuli were mixed with chimeras. The Authors found that RTs in response to living (and structurally similar) items were slower than to non-living (and non structurally similar) ones and that this effect was larger in the naming task than in the OD task. Their interpretation was that increased perceptual competition (as in the structurally similar stimuli) produces more interference especially at the level of name selection.

Starrfeld and Gerlach (2007) compared the OD task with a color decision task and a categorization task. Their findings revealed a trend for RTs in the OD task to be slower than in both other tasks; in addition, more errors were made during object decision.

Finally, Gerlach and coworkers (2006) found that in an OD task natural objects were processed more efficiently than artefacts when presented as fragmented forms, but less efficiently than artefacts when presented as outlines (Gerlach et al. 2006).

Summing up, literature evidence suggests the following:

- The distinction between Kroll & Potter's and real pictures is the easiest task, probably because Kroll & Potter's pictures are processed as non-objects and require only a minimal degree of perceptual differentiation;
- rejecting chimeras is the most difficult task, even more difficult than accepting real items, maybe because they are object-like images (the strategy employed with the Kroll & Potter's pictures is probably not anymore valid with these items, since they are made of parts of real objects; thus, it is more likely that participants may try to match chimeras to stored mental images stored);
- within real items, a category effect is often observed: healthy subjects tend to react more quickly to artefacts than to living items.

Imaging findings

Gerlach and colleagues carried out a series of behavioral and PET studies on healthy subjects in order to investigate category-specificity in visual object recognition.

What emerges from their studies is that OD is associated with extensive bilateral activation in the posterior and ventral parts of the brain, but also in the frontal cortex (Gerlach et al., 1999, 2006, 2009). More specifically, they identified two stages in the recognition process: the first, called *Shape Configuration*, is mediated by the posterior parts of the inferior temporal gyri (BA 37), the posterior and middle parts of the fusiform gyri (BA 19 & 37) and the peristriate cortex (BA 19); the second, called *Shape Selection*, is mediated by the anterior parts of the fusiform gyri (BA 20) and the inferior frontal gyri (BA 47).

According to these Authors, the Shape Selection stage could correspond to the Structural Description System.

No activation was found in the anterior and lateral parts of the temporal lobes, areas that are typically associated with semantic processing: this finding is interpreted by the Authors as a proof that object decision is primarily based on pre-semantic structural processing.

Kellenbach et al. (2005) investigated PET activation of temporal lobe regions during the retrieval of structural, color and encyclopedic information of familiar objects. The OD task activated the right posterior middle/inferior temporal gyri (BA 37) and the left middle occipital lobe (BA 19). In line with Gerlach et al., these Authors took their results as an index of a purely structural, rather than semantic, process.

In conclusion, imaging studies in healthy subjects support the idea that the OD task activates the posterior and ventral parts of the brain and that the Structural Description System may be located bilaterally, in the anterior part of the fusiform gyri (Gerlach et al., 1999, 2006, 2009).

2.2 AIM OF THE STUDY

One critical issue in the cognitive neuropsychology of visual object recognition is whether the SDS is a pre-semantic independent store, or is a subcomponent of the semantic system. Several case reports suggest possible dissociation between SDS and conceptual knowledge impairments (Riddoch & Humphreys., Hillis & Caramazza, 1995; Sheridan & Humphreys, 1993; Kellenbach et al., 2005; Gerlach et al., 1999, 2006, 2009), but evidence supporting an interaction between the two systems has also been gathered (Sartori et al., 1993; Srinivas et al.,1997; Rogers et al., 2003; Acres et al., 2009).

In the present study we aimed at further investigating the relationship between the SDS and semantic memory in a sample of young healthy participants.

We created a novel OD task where we systematically manipulated the structural, visual and semantic characteristics of the stimuli, in order to isolate the variables that may influence object recognition in healthy individuals.

More specifically, we included unreal objects in which we manipulated the overall proportion (Metrical items) or in which we rearranged the spatial relationship between object parts (Scrambled items), Kroll & Potter pictures and chimeras. Within the category of chimeras we manipulated the relatedness of the two parts composing the chimera (Unrelated and Semantically Related). A more detailed description of these categories is described in the following paragraph.

Metrical and Scrambled objects allow us to investigate whether the analysis at Structural Description level is based on features processing or on whole-object processing.

The manipulation of the conceptual relatedness between chimera parts will help us at disentangling the role of semantic memory during object decision. We predict that if reality decision may be performed with no access to conceptual knowledge, no difference will emerge between related and unrelated chimeras. On the contrary, the evidence of a worst performance on related with respect to unrelated chimeras would support an independence between the two systems.

2.3 SUBJECTS, MATERIALS AND METHODS

2.3.1 Participants

Twenty young healthy participants (6 male and 14 female; mean age 29.1 years ± 4.4, mean education 18.0 years ± 0.0), participated in the study. They were all native Italian speakers and were right-handed, as assessed by Oldfield's (1971) Inventory.

None of the participants had a history of neurological or psychiatric disorder, or of learning disability. They were all screened for normal or corrected-to-normal visual acuity.

All gave written informed consent to the experiment.

2.3.2 Task Construction

We selected 300 black and white line drawings of real objects or animals taken from the web or from published sets of pictures (not protected by copyright). By manually modifying this pool of real stimuli pictures, we created the following sub-categories of unreal animals and objects:

1. 30 drawings with METRICAL alterations (15 animals and 15 artifacts), created by manipulating the size of objects parts, such as shortening the legs of a donkey or lengthening a rod bike
2. 130 CHIMERIC stimuli, each created by combining two halves of two real animals or objects, while manipulating the relatedness of the two parts. The following stimuli were obtained:

- Artifacts:

  -Unrelated Chimeras (e.g. a gun plus a trumpet)

  -Semantically Related Chimeras (e.g. a lamp bulb plus a candle)

  -Same Manipulation Chimeras (e.g. a microphone plus an ice-cream cone).

- Animals:

  -Unrelated Chimeras (e.g. the body of a fish plus the head of a pig)

  -Semantically Related Chimeras (e.g. the body of a cow plus the head of a pig).

3. 15 SCRAMBLED drawings, for the man-made category only, were created by cutting up and rearranging real object pictures.

In addition to these sub-categories, we included a group of non-objects taken from the set of pictures originally created by Judith Kroll and Mary Potter in 1984.

Some examples of the stimuli are shown in the Appendix (page I).

Following the procedure employed by Snodgrass & Vanderwart (1980), 20 healthy volunteers were presented with all of the real drawings and asked to rate the following aspects: (a) *familiarity* (i.e. "the degree to which you come in contact with or think about the corresponding concept"); (b) *visual prototypicality* (i.e. "how closely each picture resembles your mental image of that object or animal"); (c) *age of acquisition* of the lexical label referring to the picture (i.e. "the age at which you presume to have was first learned a word").

Visual complexity (i.e. "the amount of detail or intricacy of line in the picture") was also rated, both for real and unreal stimuli.

Finally, as a verification of our a priori subgroup partition, we asked subjects to rate how much the two real objects composing each chimera:

- were semantically related,

- were structurally similar,
- required the same manipulation (only for artifacts)

All ratings were expressed on a Likert scale ranging from 1 (very low) to 7 (very high), with the exception of semantic relatedness, structural similarity and manipulation, which were rated on a scale ranging from 1 (very low) to 5 (very high).

2.3.3 Ratings Analysis

Once we had collected all ratings, a selection of items was carried out, excluding those stimuli that obtained the worst agreement. One-hundred and twenty natural pictures and 140 artifacts were finally included and analyzed. Since the data were not normally distributed in some categories, a non parametric test for independent conditions (Mann-Whitney test) was employed.

Naturals vs Artifacts

No difference was found between real animals and real objects for familiarity, age of acquisition or visual complexity. Pictures of real animals were considered significantly more prototypical than those of real objects (see Table 2.1).

Table 2.1

	Naturals	**Artifacts**	**U**	***p***
Familiarity	4.50 ± 1.36	4.55 ± 1.29	2224.00	.908
Age of Acquisition	3.84 ± 1.32	3.86 ± 1.45	2218.50	.889
Visual Complexity	4.27 ± 1.29	3.87 ± 1.14	1826.00	.06
Visual Prototypicality	6.63 ± 0.39	5.93 ± 0.74	777.50	< .001

Visual Complexity of Real vs Unreal items

The comparison of visual complexity between all real and unreal items did not show any statistically significant difference (real pictures: 4.05 ± 1.22, unreal pictures: 4.07 ± 1.11; U= 11473.00, *p*= .859).

Ratings of Chimeric stimuli

Naturals:

Semantically Related chimeras were actually significantly more semantically related (3.34 ± 0.73) than Unrelated chimeras (1.69 ± 0.55) (U = 31.50, *p* < .001), as well as significantly more structurally similar (Related: 2.30 ± 0.96; Unrelated: 1.69 ± 0.55; U = 136.50, *p* < .001).

Artifacts:

Semantically Related chimeras showed significantly higher semantic relatedness with respect to Unrelated chimeras (Related: 4.28 ± 0.54; Unrelated 1.39 ± 0.44; U = 0.00, *p* < .001), while structural similarity (Related: 2.22 ± 1.13; Unrelated: 1.89 ± 0.61; U = 135.50, *p* = .798) and manipulation similarity (Related: 1.57 ± 0.99; Unrelated: 1.16 ± 1.02; U = 115.50, *p* = .212) were overlapping.

As expected, the comparison between Unrelated and Same Manipulation chimeras evidenced a significant difference of manipulation similarity (Same Manipulation: 3.1 ± 0.98; Unrelated: 1.16 ± 1.02; U = 20.00, *p* < .001) and of structural similarity (Same Manipulation: 3.24 ± 0.88; Unrelated: 1.89 ± 0.61; U = 34.50, *p* < .001), but not of semantic relatedness (Same Manipulation: 1.55 ± 0.55; Unrelated: 1.39 ± 0.44; U = 128.00, *p* = .250).

Finally, Semantically Related and Same Manipulation chimeras differed from each other for semantic relatedness (Semantically Related: 4.28 ± 0.54; Same Manipulation: 1.55 ± 0.55; U = 0.00, *p* < .001), structural similarity (Semantically Related: 2.22 ± 1.13; Same Manipulation: 3.24 ± 0.88; U = 136.50, *p* < .001) and manipulation similarity (Semantically Related: 1.57 ± 0.99; Same Manipulation: 3.1 ± 0.98; U = 22.00, *p* = .001).

Visual complexity of real and unreal categories

Naturals:

We compared each natural subgroup with each other and found no significant difference in visual complexity (see Table 2.2).

Table 2.2

	Real Animals (4.28 ± 1.29)	**Metrical Animals (4.01 ± 0.70)**	**Unrelated Chimeras (4.12± 1.16)**	**Related Chimeras (4.04 ± 1.32)**
Metrical Animals (4.01 ± 0.70)	U = 279.00 *p* = 0.723			
Unrelated Chimeras (4.12± 1.16)	U = 817.50 *p* = 0.479	U = 142.50 *p* = 0.815		
Related Chimeras (4.04 ± 1.32)	U = 571.00 *p* = 0.350	U = 90.50 *p* = 0.427	U = 307.00 *p* = 0.670	
Kroll & Potter (4.32 ± 0.98)	U = 1013.00 *p* = 0.775	U = 148.50 *p* = 0.468	U = 443.50 *p* = 0.283	U = 298.50 *p* = 0.156

Comparison of visual complexity among each subcategories of natural items

Artifacts:

Few significant differences emerged from comparisons within artifact subgroups, as shown in Table 2.3.

Table 2.3

	Real Objects (3.87 ± 1.14)	**Metrical Objects (3.40 ± 1.12)**	**Scrambled Objects (3.90 ± 0.89)**	**Unrelated Chimeras (4.30 ± 0.95)**	**Semantically Related Chimeras (4.34 ± 1.64)**	**Structurally Similar Chimeras (3.47 ± 0.88)**
Metrical Objects (3.40 ± 1.12)	U = 285.00 *p* = 0.219					
Scrambled Objects (3.90 ± 0.89)	U = 646.00 *p* = 0.778	U = 60.00 *p* = 0.149				
Unrelated Chimeras (4.30 ± 0.95)	U = 60350 *p* = 0.103	U = 50.00 ***p* = 0.020**	U = 139.50 *p* = 0.163			
Semantically Related Chimeras (4.34 ± 1.64)	U = 400.50 *p* = 0.306	U = 90.50 *p* = 0.427	U = 94.50 *p* = 0.373	U = 125.50 *p* = 0.701		
Same Manipulation Chimeras (3.47 ± 0.88)	U = 389.50 *p* = 0.249	U = 63.00 *p* = 0.907	U = 79.50 *p* = 0.132	U = 67.50 ***p* = 0.013**	U = 59.00 *p* = 0.204	
Kroll & Potter (4.32 ± 0.98)	U = 986.00 ***p* = 0.036**	U = 88.50 ***p* = 0.018**	U = 250.00 *p* = 0.221	U = 345.50 *p* = 0.826	U = 216.00 *p* = 0.789	U = 111.50 ***p* = 0.007**

Comparison of visual complexity among each subcategories of artificial items

2.3.4 Experiment

A schematic view and some examples of the final stimuli included in the task are presented in the Appendix (page IV).

Stimuli were presented at the center of a computer screen using a software for stimulus presentation (E-prime); response speed and accuracy were recorded.

Each trial sequence consisted of a blank screen displayed for 1000 ms, followed by a central fixation cross displayed for 500 ms, followed by the stimulus, which remained on the screen until the subject pressed the response key.

Participants were instructed to decide as quickly and accurately as possible whether the stimulus represented the picture of a real or unreal artifact or animal and to respond by pressing with two hands the “REAL” or “UNREAL” button.

Eight practice trials were given at the beginning of the experimental session and a short break was given halfway.

Subjects were assigned to one of four lists created to counterbalance the order of presentation of the animals and objects and the hand used for the response key.

Reaction times and accuracy were recorded.

2.3.5 Data Analysis

LogRTs and response accuracy were analyzed using mixed-effects models (Baayen, Davidson & Bates, 2008), which combine the advantages of logistic regression with the ability to account for random subject and item effects.

RT analysis was performed only on correct responses. Responses with particularly long or short latencies (defined as two or more SDs from RT mean) were considered as outliers and excluded from the analysis.

Accuracy analysis was performed with a logistic model since the dependent variable is dichotomous (correct = 1; incorrect = 0) (Jaeger, 2008).

The following factors were considered: *Category* (Animals vs Objects), *Stimulus Type* (Real vs Non-Real) and *Subcategories* (Kroll & Potter, Metrical, Unrelated Chimeras and Semantically Related Chimeras for both Objects and Animals; Scrambled objects and Structurally Similar Chimeras for Objects only).

2.4 RESULTS

2.4.1 Effects of Category and Stimulus Type

Accuracy

The analysis did not show any significant effect of "Category" (p = 0.57), while a significant effect of "Stimulus Type" emerged, with a better performance for Unreal than Real pictures (p = 0.001). A significant interaction between "Category" and "Stimulus

Type" (*p* = 0.009) was also detected, with better performance in the natural category for unreal with respect to real items, while the opposite holds for objects (see Figure 2.1).

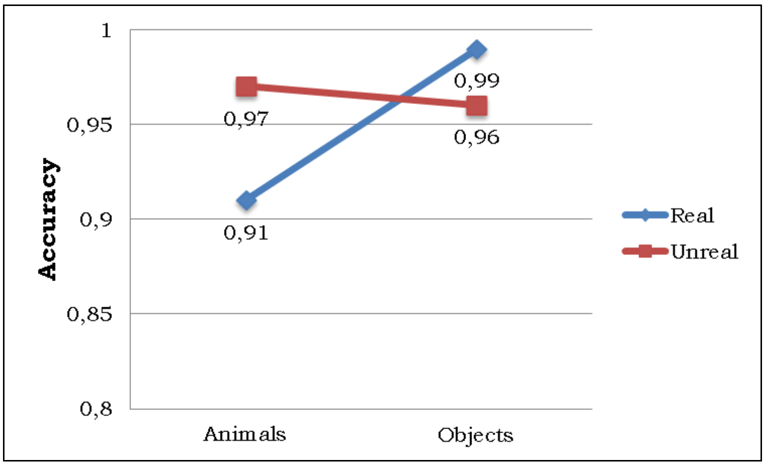


Figure 2.1 Mean Accuracy for real and unreal items (animals and objects)

Reaction Times

The RT analysis replicated quite closely the findings obtained in the accuracy analysis. The only exception was a significant effect also for "Category", with faster responses to natural items than to artifacts (*p* = 0.03) in addition to the significant effect of "Stimulus Type" with faster responses to unreal than to real stimuli (*p* = 0.001). Such effects can again be interpreted considering the significant interaction between these two variables (p = 0.001), with faster responses to the natural category for unreal items, and the opposite for artifacts (see Figure 2.2).

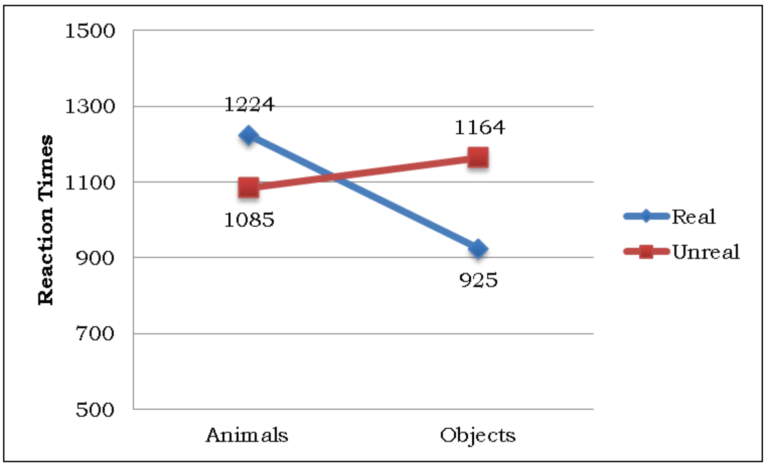


Figure 2.2 Mean Reaction Times (msec) for real and unreal items

Since visual prototypicality was the only item characteristic that differed significantly between categories, with higher values for animals than for objects, we repeated the analysis covarying for prototypicality. The effects reported above survived covariance.

2.4.2 Comparison among Subcategories of Unreal Stimuli

Accuracy

For natural stimuli, logistic regression showed that subjects performed almost at ceiling in the Kroll & Potter, Metrical and Unrelated categories, while significantly more errors were produced for Semantically Related chimeras with respect to all others categories (Fig. 2.3).

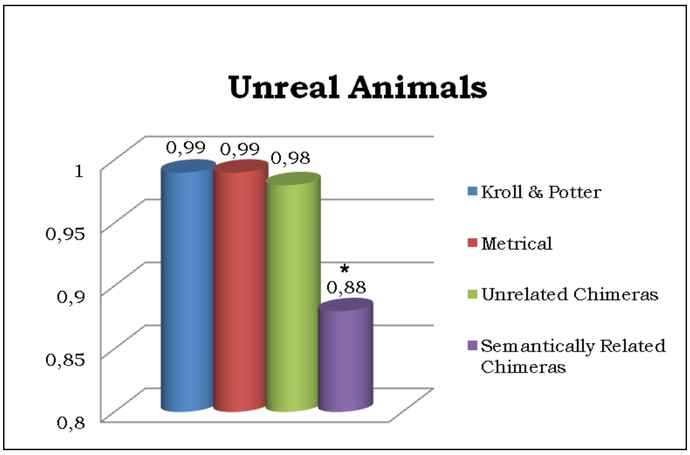


Figure 2.3 Mean accuracy in the subcategories of unreal animals. * $p < 0.001$ versus all the other groups

The same results held for accuracy within the subcategories of Unreal Objects: participants obtained the best performance with Kroll & Potter pictures, and performed almost flawlessly also with Metrical, Scrambled and Unrelated Chimeras. The accuracy was, instead, significantly lower for Same Manipulation and Semantically Related chimeras, with no significant difference between these categories. (see Fig. 2.4).

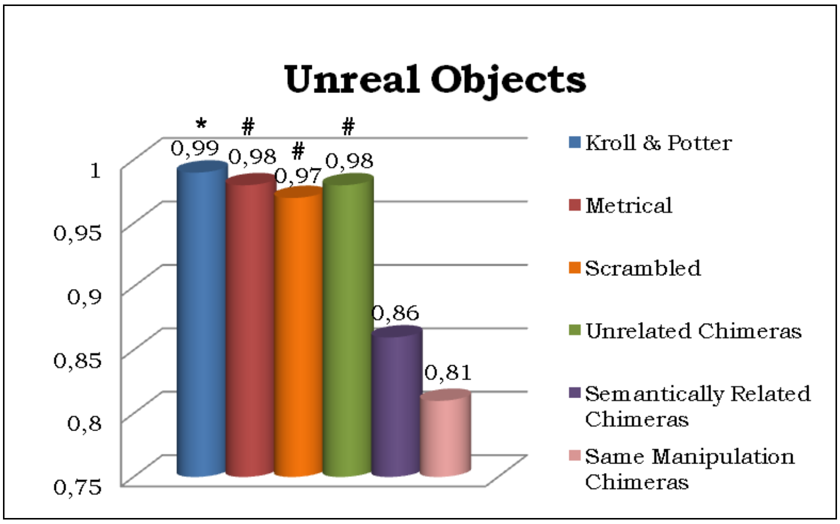


Figure 2.4 Mean accuracy in the subcategories of unreal objects.
*** *p* < 0.05 versus all; # *p* < 0.05 versus Semantically Related and Same Manipulation chimeras.**

<u>Reaction Times</u>

For natural stimuli, logRTs were significantly faster at for the Kroll & Potter pictures and stimuli with Metrical alterations. Reaction times increased when participants were asked to judge the reality of Chimeric drawings, regardless of relatedness (Fig. 2.5).

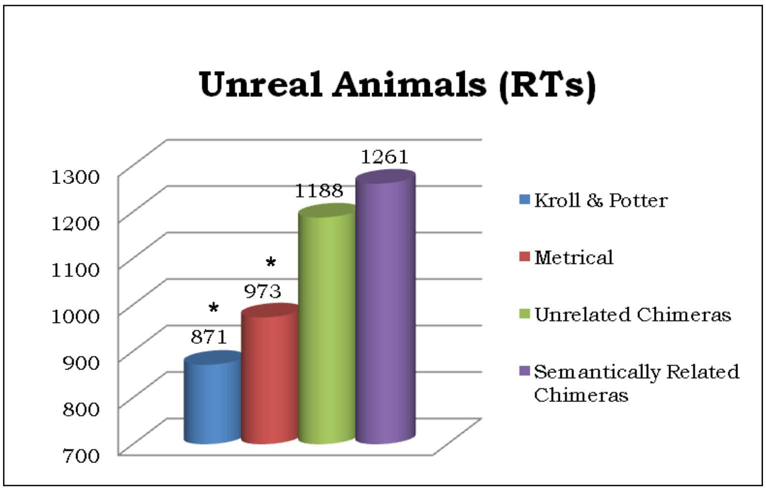


Figure 2.5 Mean Reaction Times in the subcategories of unreal animals. * $p < 0.005$ versus both unrelated and semantically related chimeras.

As to artifacts, the fastest RTs were obtained with the Kroll & Potter pictures, which were significantly different from all the other categories. The slowest RTs were observed for Same Manipulation and for Semantically Related Chimeras (with no significant difference between these two categories). Metrical, Scrambled stimuli and Semantically Unrelated Chimeras obtained intermediate response speed values, with no differences between them, but with a significant difference with respect to Kroll & Potter and to Same Manipulation and to Semantically Related Chimeras (see Fig. 2.6).

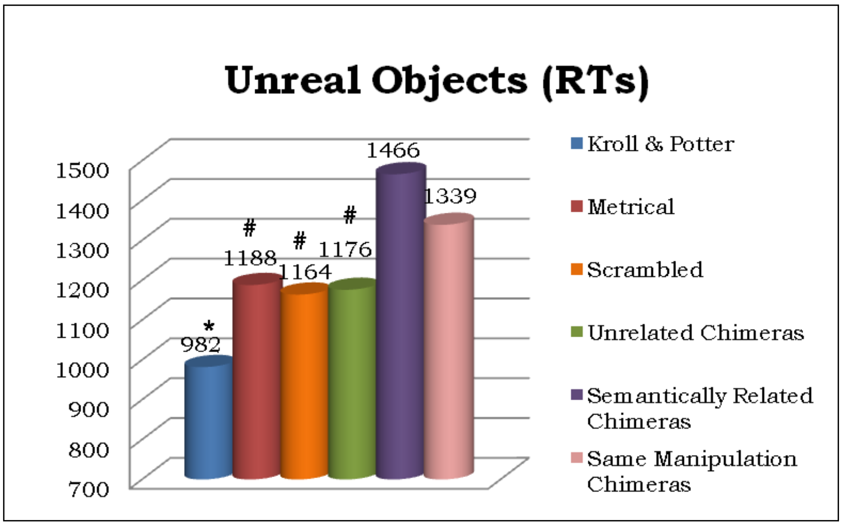


Figure 2.6 Mean Reaction Times (msec) in the subcategories of unreal objects. * $p < 0.05$ versus all; # $p < 0.05$ versus Semantically Related and Same Manipulation chimeras.

Since visual complexity was higher for some categories of unreal objects (Kroll & Potter pictures, Unrelated and Same Manipulation chimeras), we repeated the analysis covarying for this variable. The significant effects survived covariance.

2.5 DISCUSSION

The current study was designed with the general aim to help clarifying the relationship between Structural Description System and conceptual knowledge.

More precisely, we explored which characteristics of pictorial stimuli influence the performance of young healthy participants in a novel Object Decision task, with an emphasis on: Category (natural versus artificial), Stimulus Type (real versus unreal), and visual and semantic variables (metrical and scrambled alterations, semantic relatedness and visual similarity).

2.5.1 Category and Stimulus Type Effects

Consistently with the data reported in literature on normal subjects (Lloyd-Jones & Humphreys, 1997; Gerlach et al. 1999, 2001, 2006; Kahlaoui et al., 2007), our subjects obtained faster reaction times (RTs) and better accuracy for real objects with respect to real animals. The explanation for this finding is rather established: animals are more difficult to differentiate than artifacts because they are more visually similar and share more common parts with other members of their category. Consequently, a larger range of related representations are activated in visual long-term memory and compete during stimulus selection (Lloyd-Jones & Humphreys, 1997; Humhreys & Forde 2001; Gerlach et al, 2009).

Consistent evidence of an advantage for artifacts over animals is provided by Magnié and colleagues, who found that strongly manipulable objects, the great majority of which were tools, were associated with shorter RTs and lower error rates than unmanipulable objects, which were mainly living entities (Magnié et al., 2003).

Turning to the effect of stimulus type, in the present study we found better performance with unreal than real stimuli for natural items, and the opposite (i.e. better performance with real stimuli) for artifacts.

In most of the reported studies, healthy subjects responded faster and more accurately to real items than to chimeras (Lloyd-Jones & Humphreys, 1997; Gerlach et al. 1999, 2001, 2006; Kahlaoui et al., 2007) and this observation was considered a proof that the OD task is performed by matching both real and unreal pictures to representations stored in memory (Gerlach, 2001).

Nevertheless, it is worth noticing that in most previous studies that utilized chimeras, these unreal stimuli were created without taking into account the relatedness between the two halves, thus mixing related with more unrelated chimeras composed, while in our novel OD task the relatedness between the two stimuli composing the chimera was considered as a key variable. Moreover, only few studies compared real items, chimeras and Kroll & Potter pictures. In one of them Magnié and colleagues found that the subjects' performance differed significantly across the three conditions: RTs were shortest for Kroll & Potter pictures, intermediate for real objects and longest for chimeric stimuli (Magnié et al. 2003). The authors' conclusion was that when investigating picture processing it is important to distinguish between different types of unreal stimuli. Furthermore, the Authors pointed out that the slower RTs to chimeric objects with respect to real objects cannot be attributed to the fact that they require a "no" response, since Kroll & Potter pictures also require rejection, and yet were associated with faster RTs.

The fact that Kroll & Potter pictures are processed in a very effortless way can also account for the fast and accurate performance with unreal natural stimuli. Kroll & Potter pictures were indeed easier to reject, probably because, as already mentioned, they are processed as non-objects and require only a minimal degree of perceptual differentiation. Also animals with metrical alterations are quite easy to process. This may be due to the fact that the reign of animals is characterized by some general visual constraints, which are violated by these two kinds of stimuli (as, for instance, the proportion between legs the body length of an animal). On the other hand, with artificial items the Kroll & Potter pictures and the tools with metrical alterations were more challenging, since a greater variability is allowed in the category of man-made objects.

2.5.2 Effects of Visual and Semantic Characteristics of Unreal Stimuli

Previous studies on Object Decision, rarely investigated the effect of visual and semantic manipulation of unreal items. Our findings clearly show that these variables play a fundamental role in a reality decision task.

The analysis of RTs and accuracy depicted a similar pattern of results.

As already discussed, Kroll & Potter pictures were extremely easy to reject, possibly because they are processed as non-objects, with no need to access the structural description system to perform the reality judgment: only when the stimuli are “object-like” (such as stimuli with metrical alterations, scrambled objects and chimeras), they have to access the SDS and undergo further processing (analysis of spatial features and of the spatial relationship among the object constituents and matching of the shape with previously stored representations).

The evidence of a good performance with these two categories, confirms that young adults may process object as a whole and not by single-features analysis. This result is in line with the study of Davidoff and Roberson (2002), in which they demonstrated that the ability to recognize animals as a whole is not reached until the age of 16, as it happens for face recognition (young children recognize faces by parts, while older children may process faces as a whole and, in particular, take advantage of spatial relationship between internal features).

In the present study we also investigated the effect of manipulating the semantic similarity between the two halves of a chimera. Our findings suggest that this variable strongly influences object processing.

As a matter of fact, semantically related and same manipulation chimeras obtained the highest reaction times as well as the highest error rate.

One could argue that this effect could be related to the fact that the two halves composing these stimuli often share a similar shape, as, for example, in the case of related animal chimeras and same manipulation tool chimeras.

However, there is evidence in literature that object recognition is influenced more by semantic features, such as manipulability, than by structural similarity.

Campanella & Shallice (2011), for example, in a series of behavioral experiments found that repeated presentation of pairs of objects sharing a similar type of manipulation (such as pincers and a nutcracker) leads to an increasing number of errors and that this effect was stronger than that produced by two objects that only share visual similarity (such as pincers and compasses). This finding represents a direct proof of manipulability being a semantic dimension. According to these Authors, the way by which an object is actually manipulated influences its recognition by activating its semantic representations.

Moreover, several previous studies showed evidence for a link between manipulability and object recognition in that the action required to manipulate an object is implicitly retrieved in tasks requiring the recognition of the object and influences its identification (Creem & Proffitt, 2001; Helbig et al., 2006; Myung et al., 2006).

Further evidence to the fact that semantic information plays a role during reality decision comes from the finding that our sample shows a worse performance with semantically related than with unrelated tool chimeras, despite these two categories of stimuli have the same, low, structural similarity.

It seems so that healthy subjects are very sensitive to the semantic distance between the two parts of the chimeras and, in order to solve the task, they have to resolve competition between coactivated semantic competitors (Jefferies & Lambon-Ralph, 2006).

The evidence of an implication of semantic knowledge during object decision goes against the "pre-semantic" theories of object recognition, according to which the SDS should be independent from semantic memory and there should not be need to access conceptual knowledge while judging the reality of a stimulus (Riddoch & Humphreys, 1987; Sheridan & Humphreys, 1993; Hillis & Caramazza, 1995; Kellenbach, 2005; Gerlach, 2009). This view seems hardly compatible with our findings, which are, on the contrary, in favor of an interaction between the two stores. We thus suggest that the OD task entails access to conceptual knowledge rather than to purely perceptual representation.

Gerlach and colleagues consider the neuroimaging evidence of lack of activation in the more anterior parts of the temporal lobe as a proof that the OD task does not activate areas typically involved in semantic processing. Nonetheless, a recent study by Mion et al. (2010) tried to address the neuroanatomical basis of semantic memory using imaging data of patients with semantic dementia. The Authors demonstrated that the most rostral portions of the fusiform gyri represent a crucial component of the human semantic network: hypometabolism in this region provided the best account for impairment on three semantic tests (object naming, category fluency and a non-verbal associative semantic task). Another central and unexpected finding was the absence of high correlation between task scores and hypometabolism in the temporal poles. Thus, it is "*more likely that the 'hub' for general, amodal semantic concepts should be placed in the rostral fusiform gyrus*" (Mion et al., p. 3263-3264).

In light of these recent results, the pattern of activation (which includes the fusiform gyri) described by Gerlach et al. (e.g 2009) in association with an OD task, does not rule out the involvement of semantic memory.

Our suggestion that the SDS may interact with the conceptual system, seems consistent also with the performance of patients described by Humphreys & Riddoch (1987b) and by Hillis & Caramazza (1995). The chimeras employed in these studies were created by merging two very different kinds of animals or objects (such as a half giraffe and a half duck), similarly to our unrelated chimeras. Due to the visuo-semantic disconnection that is typical of patients affected by associative visual agnosia and optic aphasia, J.B. and D.H.Y. could only lean on the analysis of the form of the stimuli. Since these stimuli could be considered rather easy to reject, it is possible that the shape analysis proved to be an adequate strategy to solve the task. In normal conditions, however, the default strategy seems to imply an interaction with conceptual knowledge, as demonstrated by our findings. A similar explanation arises from the double strategy (semantic and purely visual) account proposed by Zannino and colleagues (2011).

2.6 CONCLUSION

The present study showed that the Object Decision task cannot be considered a purely perceptual or pre-semantic task; by contrast, our findings are in favor of an interaction between the structural description system and semantic memory.

According to this hypothesis, once a preliminary analysis is completed, the stimulus enters the SDS, where the spatial features and the relationships between the object constituents are elaborated and the shape of the object is matched with those previously seen. However, to perform a plausibility judgment, an interaction with the conceptual knowledge seems to be necessary.

Similarly to what posited by Zannino et al. (2011), our hypothesis is that, in normal conditions, subjects adopt a semantic strategy when judging for reality an object or an animal. In case of a visuo-semantic disconnection, this step is skipped and the reality judgment may occur only on the basis of shape analysis.

In conclusion, Object Decision does not seem to rely on a single ability: the task is heavily influenced by the type of stimuli employed, and is not necessarily independent from semantic knowledge.

CHAPTER 3

OBJECT DECISION UNDER SEMANTIC AND VISUO-PERCEPTUAL IMPAIRMENT: EVIDENCE FROM NEURODEGENERATIVE PATIENTS

3.1 INTRODUCTION

As already mentioned in the previous chapters, a new approach to the question of whether semantic knowledge affects performance on the Object Decision (OD) task comes from studies on patients with Semantic Dementia (SD).

Semantic Dementia is a neurodegenerative condition characterised by a relatively selective and progressive deterioration of semantic knowledge, resulting in word-finding difficulties, impaired comprehension of the meaning of words and concepts, surface dyslexia and associative visual agnosia. The loss of semantic knowledge appears to occur across all semantic domains and across modalities. Structural and functional imaging studies have revealed anterior and inferior temporal lobe and anterior fusiform gyri degeneration, often bilateral, but in general with major involvement of the left hemisphere (Mummery et al., 2000; Bright et al., 2008; Mion et al., 2010).

It is generally believed that, despite the often severe semantic impairment, other cognitive functions such as episodic memory, executive skills and visuo-spatial functions, remain relatively intact. Nevertheless, recent studies questioned this view by showing a breakdown on a number of tasks typically thought to be pre-semantic such as reading aloud, spelling to dictation and lexical or object decision (Patterson et al., 2006; Caine et al., 2009; Jefferies et al., 2010).

The evidence that SD patients may show impaired performance at object recognition has challenged the functional and neuroanatomical separation of the Structural Description System (SDS) from semantic memory (Hodges et al., 1994; Hovius et al., 2003; Rogers et al., 2003; Patterson et al., 2006; Zannino et al., 2011).

More specifically, according to the most recent theories, OD cannot be considered as a single ability relying on a single system (i.e. the SDS); rather, it would always require both complex visual processing and access to semantic knowledge (Hovius et al., 2003).

According to some authors, by manipulating the nature of the stimuli or by comparing two different types of OD tasks (for example the Visual Object and Space Perception battery - VOSP OD test versus the Birmingham Object Recognition Battery - BORB OD test), one can vary the degree to which semantic memory is taxed (Hovius et al., 2003; Rogers et al., 2003).

In agreement with this hypothesis, Zannino et al. (2011) recently proposed that two strategies can be used when operating a reality judgment: a “semantic strategy”, that would be used as a default procedure, and a “purely visual strategy”, which is implemented only in the case of visuo-semantic disconnection. In support to this hypothesis the Authors describe the case of M.P, a patient affected by SD. She performed poorly when she had to solve a classical OD task (real objects versus chimeras); on the contrary, she performed normally when she had to judge the reality of pictures of animals or faces modified by elongating or shortening the major axis.

Studies dealing with patients affected by neurodegeneration of posterior brain areas are more scattered. Cases with Posterior Cortical Atrophy are known to have apperceptive agnosia (McMonagle et al., 2006; Alladi et al., 2007); nevertheless, to our knowledge their ability at object decision has rarely been investigated. Lehmann, Warrington and co-workers (2011) administered the VOSP battery to a group of PCA patients. Their results showed that 71% of patients were impaired at the VOSP OD task. Vineaud et al. (2008) found an impaired performance at the VOSP OD task in two PCA patients as well. Bak et al. (2006) explored visual and visuo-spatial functions in parkinsonian patients and found that the Cortico-Basal Syndrome group showed more pronounced deficits in object recognition compared with MSA (Multiple System Atrophy) and PSP (Progressive Supranuclear Palsy) patients. It is worth noticing, however, that these studies employed the VOSP version of OD task, which relies on the integrity of visuo-perceptual functions more heavily than tasks involving chimeras. More data on 'posterior' patients' performance with different types of OD tasks (for example, chimeras) should be collected.

3.2 AIM OF THE STUDY

In the previous chapter we introduced our new OD task, created in order to explore the relative weight of visual and semantic characteristics of stimuli on reality judgments. Data from a group of 20 young healthy controls demonstrated that Kroll & Potter stimuli pictures with metrical alterations and scrambled objects were easy to reject, while chimeras were more challenging. In particular, chimeras in which the two parts were semantically or structurally related to each other generated much more interference with respect to unrelated chimeras.

In the present study, we aimed at investigating what happens to OD performance when perceptual abilities or semantic knowledge are impaired. To this aim we administered our OD task to eight patients with a progressive impairment of visuo-perceptual abilities, who showed difficulties in tasks investigating the early analysis of objects shapes (such as figure-ground discrimination), and to seven patients who presented with a moderate and progressive impairment of semantic knowledge, but showed spared abilities in the early stages of object recognition.

First of all we were interested in verifying recent literature data on OD impairment in semantic dementia; in parallel, we wanted to explore how patients with dysfunction of temporo-parietal-occipital abilities behave in reality decision tasks.

Second, we aimed at comparing the performance of the two groups of patients to clarify the relative impact of visuo-perceptual and conceptual variables on object decision and recognition.

Finally, we were interesting in clarifying whether the loss of detailed semantic knowledge in SD patients, and their tendency to rely on superordinate information, might result in a lower interference effect in semantically related chimeras. As a matter of fact, according to some author SD patients are supposed to initially retain superordinate information about an item (e.g. “animal”) while losing item-specific knowledge (e.g. “elephant”).

3.3 SUBJECTS, MATERIALS AND METHODS

3.3.1 Participants

Fifteen neurodegenerative patients, with a disproportionate and progressive impairment at tests assessing verbal and non-verbal semantic memory or visuo-perceptual functions were included into the study. Patients were further subdivided in a “semantic” group (n= 7) and in a “perceptual” group (n= 8). Four semantic cases (patients R.L., G.N., O.M. and A.U.) met diagnostic criteria for Semantic Dementia (Neary et al., 1998), one (B.C.) for Fronto-Temporal Lobar Degeneration Dementia (Neary et al., 1998) two (I.V. and T.T.) for Mild Cognitive Impairment (Winblad et al., 2004) restricted to the semantic domain. Evidence of degeneration at neuroimaging scans always involved the temporal lobes, either selectively or not. Six out of eight perceptual patients were diagnosed as Posterior Cortical Atrophy (McMonagle et al., 2006) and two (I.B. and G.C.) with Cortico-Basal Syndrome (Boeve et al., 2003). See the Appendix (page V) for a brief description of the case series.

Ten control subjects, matched for age and education, were recruited. Controls were screened to rule out neurological or major psychiatric illness.

All patients were referred to the Centre for Cognitive Disorders of the San Gerardo Hospital, Monza, where they underwent clinical and cognitive assessment by a senior neurologist and a neuropsychologist. Structural brain imaging and/or functional neuroimaging data (PET/SPECT) were also collected for each participant.

Despite some variability across patients and succeeding assessments, in most cases the following neuropsychological tests had been used for general cognitive assessment: Mini-Mental State Examination (Folstein et al., 1975; Measso et al., 1993), Attentional Matrices (Spinnler & Tognoni, 1987), Digit Span (Orsini et al., 1987), Rey's Auditory Verbal Learning Test (Carlesimo et al., 1996), Rey's Complex Figure, copy and recall (Caffarra et al., 2002), Token Test (Spinnler & Tognoni, 1987), Letter and Category Fluency (Novelli et al., 1986), Raven's Colored Progressive Matrices (Basso et al., 1987), Frontal Assessment Battery (Appollonio et al., 2005), Benton Judgement of Line Orientation (Benton, 1992) and Pyramid & Palm Tree test (verbal version, Gamboz et al., 2009). Moreover, ideomotor apraxia (De Renzi et al., 1980) was assessed in all patients with posterior atrophy. Neuropsychological scores are shown in Table 3.1.

After routine cognitive assessment, patients underwent a battery for investigation of object recognition including the Poppelreuter-Ghent Overlapping Figures Test (P-GOF, Della Sala et al., 1995), the Foreshortened View task (matching of objects in unusual view, BORB, Riddoch & Humpreys, 1993), the Test for Semantic Association and the Test of Visual Completion (original, unpublished tools for the evaluation of visual semantic memory, Spartà et al., 2006) and a confrontation naming task (Laiacona et al., 1993). Scores are shown in Table 3.2.

Elderly controls were administered the Mini-Mental State Examination, the Test of Semantic Associations, the Test of Visual Completion and the Object Decision Task.

All semantic patients presented with a predominant impairment at category fluency, object naming, and verbal and visual semantic associations. Their visuo-spatial and perceptual abilities, non-verbal problem solving and non-semantic aspects of language were preserved. Few patients showed a slightly poor performance at long-term episodic memory and executive functions tasks; their scores at semantic tasks, however, were disproportionately affected.

Visuo-perceptual patients showed predominant disruption of the judgment of line orientation, figure-ground discrimination (P-GOF), copy of Rey's Complex Figure and visual completion. Few patients presented with ideomotor apraxia.

Table 3.1. Sociodemographic characteristics and neuropsychological scores of semantic and perceptual patients.

				PATIENTS WITH SEMANTIC DEFICITS							PATIENTS WITH VISUO-PERCEPTUAL DEFICITS								
	Max	Cut-off	Controls (n = 10)	R.L.	G.N.	B.C.	I.V.	O.M.	T.T.	A.U.	R.E.	I.B.	E.L.	A.R.	G.C.	A.I.	G.B.	V.B.
Age			72.3 ± 5.8	81	58	74	82	77	80	56	68	68	61	66	76	75	62	51
Education			8.9 ± 3.3	5	5	5	8	5	6	13	8	8	5	5	8	13	8	8
Sex			6 M / 4 F	M	F	F	M	F	M	F	M	F	M	M	F	M	F	M
MMSE (raw)	30	≥ 23.8	28.4 ± 1.4	30	29.74	**23.03**	28.2	26.03	25.2	25.99	24.53	**23.53**	**23.27**	24.27	26.2	27.86	26.53	17.97
Digit Span	9	≥ 3.75	/	5.5	6.5	4.5	6.25	4.5	6.5	5.75	5.25	4.25	4.5	4.5	6.25	4.75	5	**3**
Rey's words: immediate recall	75	≥ 28.5	/	38.2	34.4	**25.9**	44.5	**28**	27.2	**19**	37.9	30.7	29.7	**20.1**	30.6	**17.4**	32.5	33.5
Rey's words: delayed recall	15	≥ 4.7	/	9.8	6.2	**0**	6.8	**4.1**	**3.8**	**0**	**3.9**	4.9	**4.6**	5.8	7.4	**3.3**	**0**	8.2
Rey's figure: copy	36	≥ 28.9	/	33.25	33.5	33.75	35.75	**28.25**	30.75	30.75	33	**7**	**20.5**	**3.5**	**17.25**	**13**	**0**	**25.25**
Rey's figure: recall	36	≥ 9.5	/	21	14.25	**0**	12.75	13	15.75	**6.75**	17.25	n.a.	**8.25**	n.a.	n.a.	n.a.	n.a.	**6.75**
Line orientation (Benton)	30	≥ 19	/	/	26	/	/	/	/	29	/	**10**	22	**7**	**11**	**17**	**8**	/
Token Test	36	≥ 26.5	/	31.5	29.75	31	32.75	28.5	29	28	31	29	32.25	26.5	27.25	27	33.5	**26**
Letter fluency	-	≥ 17	/	24	28	41	32	19	26	**10**	31	24	20	**12**	33	24	45	30
Category fluency	-	≥ 25	/	24	**23**	**24**	34	**23**	28	**6**	31	26	36	**14**	**23**	**19**	37	30
FAB	18	≥ 13.5	/	12.85	15.85	18	16.25	**6.5**	15.85	**12.35**	17.65	**13.25**	**10.85**	**12.05**	13.95	**10.15**	17.25	**9.9**
Attentional Matrices	60	≥ 31	/	51.75	47.75	56.75	51.5	47.75	45.75	42	46.5	**20**	**24.25**	31.5	36.5	**21.25**	**27.25**	**16**
Raven CPM	36	≥ 19	/	33	30.5	29	30.5	29	22.5	29	28.5	24.5	20.5	30.5	**10.5**	**16**	21	**12.5**
Pyramid & Palmtrees - words	52	> 40.78	/	**40.43**	**35.25**	45.13	43.9	**36.13**	44.43	**31.74**	43.31	44.31	47.25	46.55	42.61	42.92	47.33	49.14
Other pathological tests	-	-	/	/	/	/	/	/	/	/	/	IMA	IMA, Acalculia	IMA	IMA	IMA	/	Acalculia

Max = maximum test score. Cut-off = scores adjusted for age, gender and education, according to published norms for the Italian population. IMA = Ideo-Motor Apraxia. Red text = impaired scores. N.A. = not applicable

Table 3.2. Scores obtained by patients and controls at the battery of tests for object recognition.

				PATIENTS WITH SEMANTIC DEFICITS							PATIENTS WITH VISUO-PERCEPTUAL DEFICITS							
	Max	Cut-off	Controls (n = 10)	R.L.	G.N.	C.B.	I.V.	O.M.	T.T.	A.U.	R.E.	I.B.	E.L.	A.R.	G.C.	G.B.	A.I.	V.B.
P-GOF																		
-meaningful	36	≥ 28	/	35	36	36	36	34	36	35.25	32	**26.5**	30.5	32	**26.25**	**18.5**	**23.25**	29.75
-meaningless	35	≥ 23.2	/	35	34.25	33	35	30	35	31	30.25	**20.5**	27.25	30	**19.5**	**11**	**16.25**	25.75
-total	71	≥ 51.5	/	71	70.75	69	71	64	71	66.25	62.25	**51.25**	57.75	62	**45.75**	**29.5**	**39.5**	55.5
Foreshortened view task	25	≥ 16	/	22	23	19	24	19	22	22	23	18	23	/	18	/	20	22
TVC	46	≥ 41.75*	45.1 ± 1.2	**38**	**33**	**33**	**41**	/	**40**	**23**	**37**	**31**	**40**	**37**	**35**	**40**	**26**	**40**
TSA	76	≥ 73.2*	75.3 ± 0.9	**67**	**59**	**70**	**69**	/	**66**	**43**	**70**	**69**	74	**72**	**66**	74	**53**	**72**
Naming	80	≥ 61	/	**56**	**45**	**59**	**60**	**56**	**59**	**17**	62	**55**	73	66	61	70	**48**	75

Max = maximum test score. Cut-off = scores adjusted for age, gender and education, according to published norms for the Italian population. * = Cut-offs calculated using the program proposed by Crawford et al. (2010) for the single-cases analysis; P-GOF = Poppelreuter-Ghent Overlapping Figures; TVC = Test of Visual Completion; TSA = Test of Semantic Association. Underlined text = borderline scores. Figures in red correspond to pathological scores.

3.3.2 Materials and Procedure

The task and procedure described in the previous chapter were employed to assess patients' object decision. Only accuracy was recorded.

3.3.3 Data Analysis

Statistical analysis of socio-demographic characteristics and of performance at neuropsychological tests was performed with PASW statistics, Release Version 18.0.0 (SPSS, Inc., 2009, Chicago, IL, www.spss.com). As data did not meet criteria for parametric tests, Kruskall-Wallis and Mann-Whitney tests were used to compare means of continuous variables.

Since the dependent variable of the object decision task was dichotomous (correct = 1; incorrect = 0), a mixed logit model was used (Jaeger, 2008). This analysis combines the advantages of ordinary logistic regression with the possibility to account for random subject and item effect. The following factors were considered: *Diagnosis* (Normal Controls, Perceptual Patients and Semantic Patients), *Stimulus Category* (Animals vs Objects), *Stimulus Type* (Real vs Non-Real) and *Stimuli Subcategories* (Kroll & Potter, Metrical, Unrelated Chimeras and Semantically Related Chimeras for Animals; Kroll & Potter, Metrical, Scrambled, Unrelated Chimeras, Semantically Related Chimeras and Same Manipulation Chimeras for Objects).

Different levels of analysis were carried out:

- assessment of the effect of variables *Stimulus Category* and *Stimulus Type* and of their interaction;
- comparison of performance across the subcategories of unreal items;
- measurement of the effect of visual, semantic and psycholinguistic properties of stimuli on accuracy (each of these continuous variables was tested in a separate model).

3.4 RESULTS

3.4.1. Comparison of Socio-Demographic Characteristics and Neuropsychological Scores

Normal controls and both groups of patients were comparable for age and education, while the Mini-Mental State Examination score was significantly different (H(2) = 8.84, $p < .05$) (see Table 3.3). At Mann-Whitney post-hoc tests (with Bonferroni correction leading to a .0167 level of significance) the only significant difference emerged between healthy controls and patients with perceptual deficits, who obtained a lower Object Decision score (see Table 3.4).

Table 3.3

	NC (mean ± sd)	*SP (mean + sd)*	*PP (mean + sd)*	*Chi-Square*	*df*	*Sig.*
Age	72.3 ± 5.8	72.6 ± 10.9	65.9 ± 8.1	3.392	2	.183
Education	8.9 ± 3.4	6.7 ± 2.9	7.9 ± 2.5	2.332	2	.322
MMSE (raw)	28.4 ± 1.4	25.7 ± 3.5	24.1 ± 3.2	8.837	2	.008

Kruskall-Wallis Test. NC = Normal Controls; SP = Semantic Patients; PP = Perceptual Patients.

Table 3.4

	MMSE (raw score)
Mann-Whitney U	6.000
Wilcoxon W	42.000
Z	-3.051
Sig.	.001

Mann-Whitney Test. Comparison between NC and PP MMSE raw scores.

As to visuo-perceptual and semantic tests (see Table 3.5), the analysis showed a significant difference between the two patients' groups at figure-ground discrimination, (Poppelreuter-

Ghent Overlapping Figures; P-GOF), with perceptual patients being more impaired than semantic patients (U = 5.50, $p = .006$).

Table 3.5

	SP (mean + sd)	*PP (mean + sd)*	*U*	*Z*	*Sig.*
P-GOF (total)	63.9 ± 4.7	48.0 ± 12.6	5.500	-2.61	.006
FVT	21.6 ± 1.9	20.7 ± 2.3	16.500	-0.66	.513
TVC	34.7 ± 6.2	35.1 ± 5.1	21.000	0.00	1
TSA	62.0 ± 11.0	68.6 ± 6.9	11.500	-1.62	.112
CN	50.7 + 15.9	63.8 ± 9.2	12.000	-1.86	.067

Mann-Whitney Test. Comparison between SP and PP at perceptual and semantic neuropsychological tests. P-GOF: Poppelreuter-Ghent Overlapping Figures; FVT: Foreshortened View Task (matching of objects in unusual view); TVC: Test of Visual Completion; TSA: Test of Semantic Association; CN: Confrontation Naming.

The comparison between the two groups of patients at the picture naming task showed a trend towards significance. Thus, we checked for the proportion of patients who obtained an abnormal score in each group. We found that the proportion of impaired performance at picture naming was significantly higher in the semantic patients' group (X^2 (1) = 8.75, $p =$ .007).

Summing up: as expected, perceptual patients were more impaired at those tasks that required early shape analysis (P-GOF), while semantic patients showed a worse performance when lexical functions were involved (confrontation naming).

3.4.2. Effects of Diagnosis, Stimulus Category and Stimulus Type

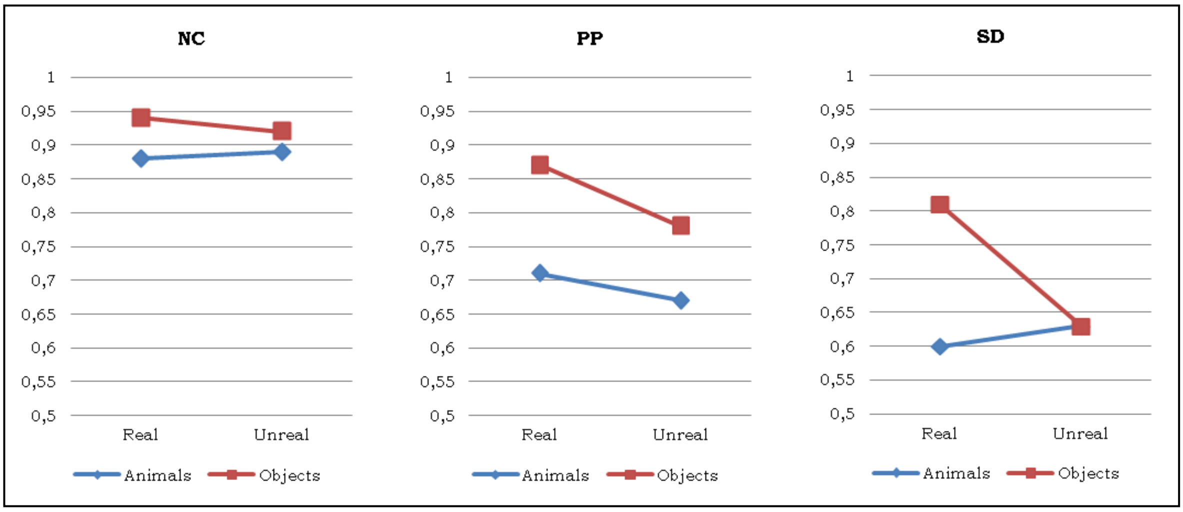
The analysis showed a main effect of diagnosis, with Normal Controls performing better than the two groups of patients ($p = 0.01$).

Taken individually, the group of Normal Controls did not exhibit a significant effect of stimulus type, while a stimulus category effect emerged, with a better performance with objects than with animals ($p = 0.02$).

Perceptual patients also showed a main effect of category, with a better performance for objects ($p = 0.01$). Furthermore, interactions showed a trend towards significance ($p = .057$), with a larger effect of real versus unreal for objects, with respect to animals (see Figure 3.1).

The same holds true for the semantic group, in which a main effect of category and a significant interaction between stimulus category and type ($p = 0.003$) were detected, with a higher accuracy for real with respect to unreal objects, that was less evident for real with respect to unreal animals.

Figure 3.1 Accuracy at the Object Decision task. Effect of Diagnosis, Stimulus Category and Stimulus Type.

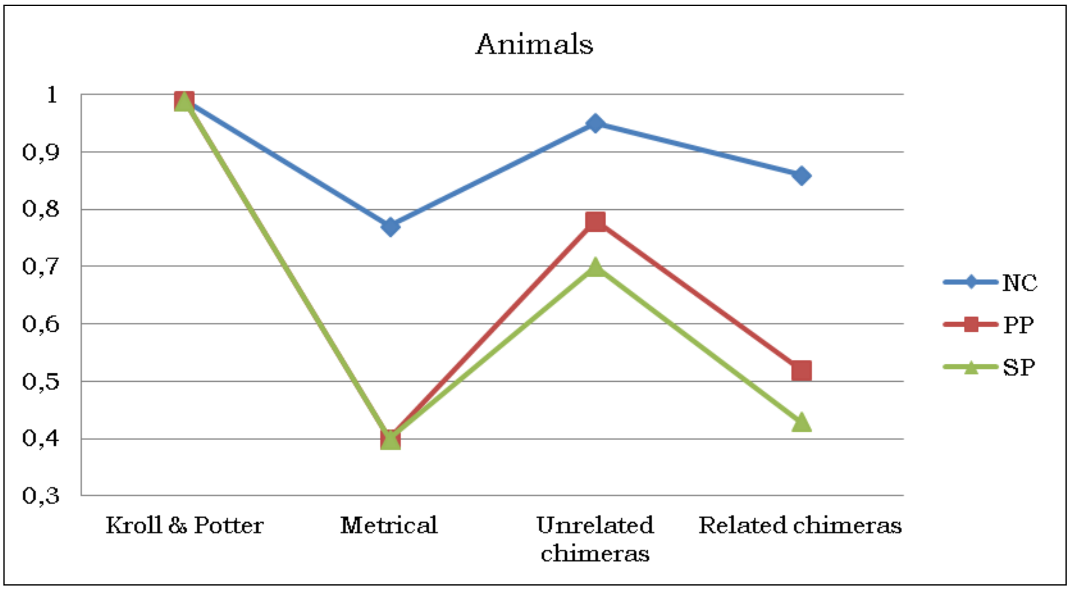


LEGEND: NC = Normal Controls; PP = Perceptual Patients; SP = Semantic Patients

3.4.3. Comparison among Subcategories of Unreal Stimuli

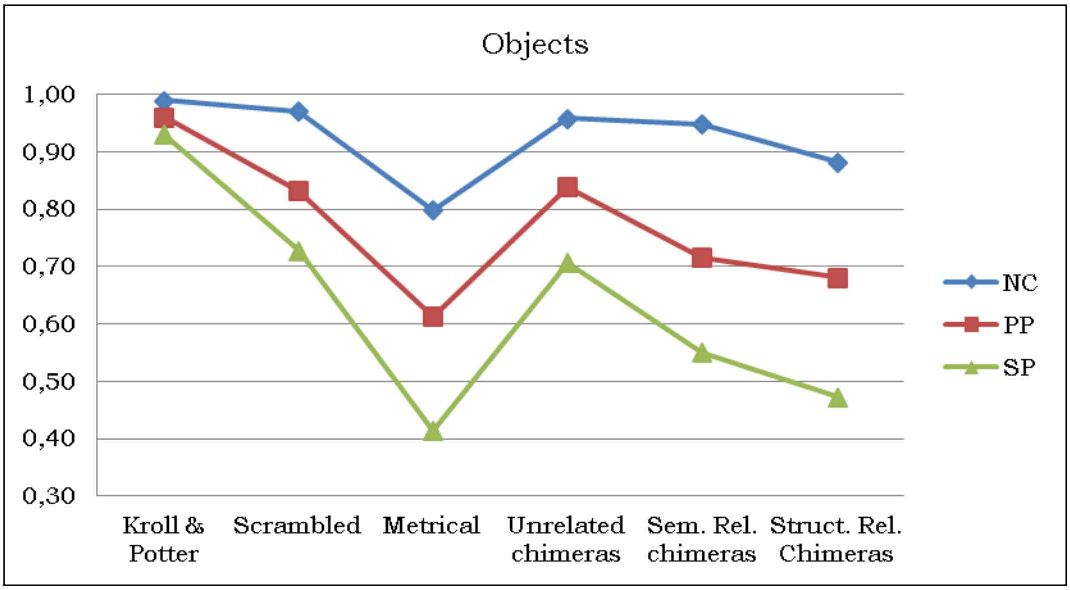
Logistic regression showed a main effect of diagnosis, with a better performance for Normal Controls with respect to perceptual and semantic patients ($p < 0.001$). For objects only, a significant difference between groups, with worst performance for semantic patients, was also found, ($p = 0.01$). Moreover, it emerged a main effect of subcategory ($p < 0.001$), with the highest accuracy for Kroll & Potter pictures, the lowest for metrical stimuli and semantically and same manipulation chimeras, and intermediate values for unrelated chimeras and, for objects only, for scrambled stimuli (Figure 3.2 and 3.3). No interactions were found. When covarying for severity of disease (MMSE) no effects emerged.

Figure 3.2 Accuracy at the Object Decision task. Subcategories of unreal animals.



LEGEND: NC = Normal Controls; PP = Perceptual Patients; SP = Semantic Patients

Figure 3.3 Accuracy at the Object Decision task. Subcategories of unreal objects.



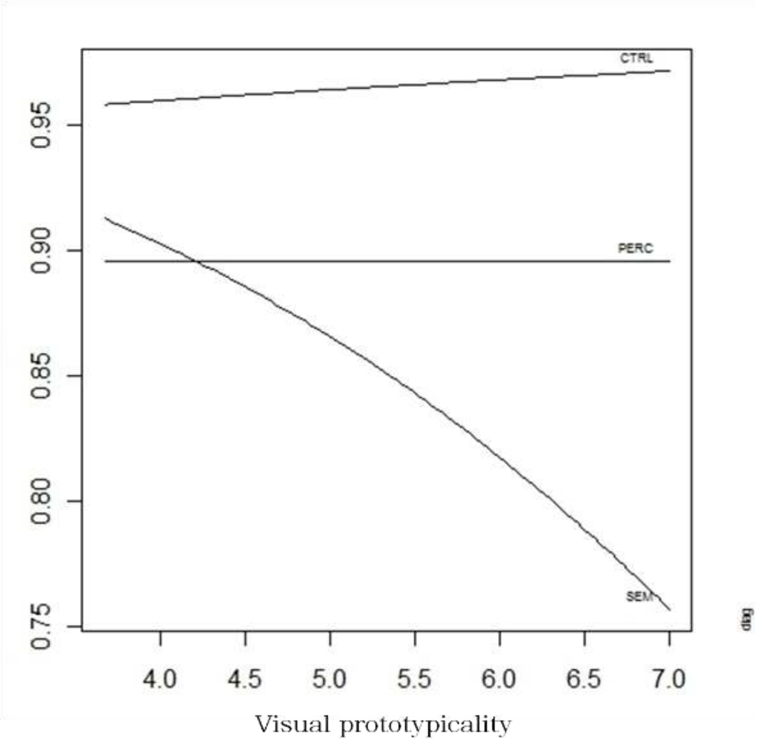
LEGEND: NC = Normal Controls; PP = Perceptual Patients; SP = Semantic Patients

3.4.4. Effects of Semantic, Visuo-perceptual and Psycholinguistic Variables

For real items we found a main effect of age of acquisition and familiarity ($p < 0.01$), with a better accuracy for stimuli that were more familiar and acquired earlier. This effect was not different between healthy controls and patients.

Conversely, a significant interaction emerged between diagnosis and visual prototypicality (i.e. “how closely the picture resembles your mental image of that object/animal?”) ($p = 0.01$): controls and perceptual patients did not show any significant effect of this variable on reality judgment, while patients with semantic deficits were *less* accurate with more prototypical drawings (Figure 3.4).

Figure 3.4 Effect of visual prototypicality on accuracy in the three groups.



For chimeras we found a main effect of semantic relatedness and structural similarity ($p < 0.01$) in the direction of a worse performance when the two parts composing the chimeras were highly semantically related or structurally similar, without differences among groups. Finally, no effect was found for visual complexity of the stimulus ($p = 0.4$).

3.5 DISCUSSION

Our findings clearly show that patients affected by a progressive degeneration of semantic or perceptual functions are impaired at an OD task.

For what concerns degenerative patients suffering from predominant perceptual disorder, they have been neglected by the literature on object recognition, so no previous study is available for comparison. Although they showed higher accuracy with some types of stimuli with respect to patients suffering from predominant semantic disorder (e.g. unreal objects), they never reached normal controls' levels of performance.

To our knowledge, this is the first time that an OD task composed by different types of unreal stimuli (including chimeras) has been employed to detect an object recognition impairment in PCA and CBS patients.

As to semantic patients, our findings are in contrast with the past view that visual object recognition is independent from semantics (Riddoch & Humphreys, 1987; Stewart, Parkin & Hunkin, 1992; Hillis & Caramazza, 1995; Rumiati & Humphreys, 1997). The crucial evidence supporting this view came from brain-damaged patients who were able to recognize line-drawings as real, despite being unable to retrieve any semantic information about them. Results obtained in patients with focal lesions, though, cannot be necessarily extended to patients affected by a degenerative brain disorder.

In spite of some exception (e.g. Lambon-Ralph and Howard -2000- described an SD patient who performed virtually perfectly), most studies on patients affected by progressive semantic deficits are in line with our finding (Hodges et al, 1994; Hovious et al., 2003; Rogers et al., 2003; Caine et al., 2009; Zannino et al., 2011). Such patients seem to be impaired at OD tasks, and this seems to be particularly evident when chimeras are employed.

Overall, our findings suggest that integrity of both visuo-perceptual and semantic functions is required in order to achieve a good level of performance at our OD task.

3.5.1 Category Effects

All our groups (normal controls and semantic or perceptual patients) showed a category effect, with a better performance with objects than with animals.

As already discussed in the previous chapter, this result is consistent with studies investigating OD in healthy subjects (Lloyd-Jones & Humphreys, 1997; Kahaloui et al., 2007; Gerlach et al, 2006, 2009). According to Lloyd-Jones and Humphreys, in biological elements, because of their structural similarity, a larger range of related representations would be activated and would compete during stimulus selection. Gerlach (2009) postulated a model named PACE (Pre-semantic Account of Category Effect in visual object recognition), based on his functional neuroimaging studies on the OD task. According to this model, the shape of natural objects is more easily configured than the shape of artifacts. However, this disadvantage of artifacts would be outweighed by the stronger competition occurring in (visual) long-term memory for natural elements. Gerlach also suggests the involvement of two distinct neural substrates: the posterior part of the inferior temporal gyrus, the posterior and middle parts of the fusiform gyrus, and the peristriate cortex (BA 37 and 19, bilaterally) would be the areas for shape configuration, while the anterior part of the fusiform gyrus and the inferior frontal gyrus (BA 20 and 47) would be activated during selection from visual memory.

This theory fits well with our results on normal controls, and also on semantic patients, who generally presented with anterior-temporal damage (see Appendix – Chapter 3). Furthermore, a better performance with artifacts in patients affected by semantic dementia or Alzheimer's disease is a well documented effect in literature, supported by converging data obtained with different types of tasks, such as picture naming, word-to-picture matching and naming to description (Zannino et al., 2006; Martinaud et al., 2009; see Capitani et al., 2003 for a review).

The disadvantage for the living category also in perceptual patients, who showed prevalent posterior temporal damage at MRI or PET, is more puzzling. According to the PACE model, these patients should be impaired at shape configuration, and they indeed obtained a poor performance at the Poppelreuter-Ghent Overlapping Figure Test. However, the PACE model would also predict a worse performance at the OD task with artifacts than with living stimuli, while our findings revealed the opposite pattern.

One possible explanation could rely on the hypothesis generated by Hovius and colleagues (2003): as already mentioned in the introductory paragraph, when designing an experiment, it is possible to vary the degree to which conceptual knowledge is taxed by manipulating the nature of stimuli and the task demands. More specifically, the more the task requires complex visual analysis, such as in the case of silhouettes of the VOSP battery, the less is the reliance on semantic knowledge (Zannino et al., 2011). On the contrary, Object Decision tasks in which chimeras are employed appear to interact with the semantic representations of objects, more than with visual complexity.

We suggest that, since our stimulus material included a large number of chimeras, we may have led our posterior patients to rely on their conceptual knowledge more than on deep, faulty, visual analysis. This could be the reason why, despite their difficulties with object shape configurations, this group of patients is still able to perform relatively well with artifacts, during a reality decision task.

3.5.2 Effects of Visual and Semantic Characteristics of Unreal Stimuli

Although the results reported in Chapter 2 (page 38) arising from our sample of 20 young controls are not fully comparable because of the different task procedures, it is worth noticing that the pattern of performance depicted by the analysis on the subcategories of unreal drawings appears to be broadly similar. Kroll & Potter pictures seem to be very easy to reject, even in case of perceptual and semantic impairment. Patients showed a relatively good performance also with scrambled stimuli and unrelated chimeras, while the accuracy decreased drastically with same manipulation and semantically related chimeras, and with stimuli with metrical alterations. These results provide further support to the idea that the more interaction is required between the perceptual and the semantic systems, the more difficult it is to perform a reality decision task.

We found, however, a difference in performance of young controls and elderly participants (demented or not) with stimuli with metrical alterations. While young subjects were very accurate with such stimuli (as accurate as with unrelated chimeras or scrambled stimuli), this ability to appreciate the metrical coherence of an object or of an animal seems to worsen with age.

One possible explanation might be that the processing of proportions of a global shape might become progressively more demanding with age, as differences between real drawings and their metrical transformation might be too subtle for old people to detect.

One alternative explanation could reside in the fact that the ability to recognize a shape by the relative scale of its elements (i.e. wholes), rather than by its features (i.e. parts), is acquired relatively late in life, around 16 years of age (Davidoff & Roberson, 2002). A cognitive function that is acquired that late might be more vulnerable to aging (as happen, for example for late-learned words; Ellis & Lambon-Ralph, 2000).

As to the significant difference that emerged between semantically related and unrelated chimeras, our findings suggest that a progressive deterioration of semantic memory does not prevent patients to experience interference due to conceptual relatedness.

Although the statistical analysis does not show any significant interaction between patients' group and item subcategories, probably because of the great variance of performance across patients, raw data indicate that the accuracy delta between unrelated and related chimeras is much greater in semantic patients than in healthy individuals (the semantic patients' accuracy decreases of 22.6+15.4 points, while that of normal controls of only 5.8+6.6).

A tentative explanation for the semantic interference shown by semantic patients might be the fading of boundaries between subcategories. In the early stages of semantic degeneration patients might start to lose the differences between animals (or objects) belonging to the same category (e.g. a sheep and a goat), while they maintain the ability to distinguish a sheep from a bird.

As the deficit progresses, it is conceivable that all the boundaries within an animal (and object) category may be lost. At this stage patients could exhibit a behavioral effect that is known in literature as "superordinate superiority effect" (Warrington, 1975; Hodges et al., 1992, 1995; Rogers et al., 2004; Rogers & Patterson, 2007). According to this thesis, as the conceptual knowledge deteriorates, patients tend to retain general categories (such as "animal" or "tool"), while they fail to retrieve specific-level information (such as "sheep" or "hammer").

A similar reasoning can be applied also to same manipulation chimeras.

As shown in the discussion of the previous Chapter (paragraph 2.5.2), there is evidence for manipulability information being a part of the semantic representation of the objects (Campanella & Shallice, 2011). Data on our patients confirm that chimeras in which the two halves share a similar manipulation greatly interfere with stimulus recognition.

3.5.3 Visual Prototypicality Effect in Semantic Patients

As reported in the Results section, only one variable, visual prototypicality of real items, affected the OD performance of the three groups differentially. More specifically, while controls and perceptual patients did not show any significant effect of this variable on reality judgments, patients with semantic deficits were significantly less accurate with more prototypical drawings.

This finding is counterintuitive. Trying to find a possible explanation for this inverse correlation, we examined the characteristics of the pictures that had obtained highest values of visual prototypicality.

First of all, we observed that the great majority of the high-tipicality pictures belonged to the animal category. This is not so surprising, since artifacts are characterized by greater shape variability, while animals have more structural, and thus visual, constraints. Given that our semantic patients performed worse with living items, the visual typicality effect might have actually been caused by the non living versus living superiority. However, this would not explain why we did not find the same effect in the perceptual group, which was also more impaired with the living than the non living items.

We also noticed that animals that had been rated as most prototypical were all exemplars with a distinguishing and idiosyncratic visual property, such as the toucan (beak), the peacock (tail), the swordfish (nose) or the squirrel (tail). The rapid deterioration of distinctive features and the over-regularization of properties that are common to most familiar animals (such as four legs, a tail and ears) are well-documented in the literature on semantic dementia (Warrington, 1975; Luzzatti & Davidoff, 1994; Rogers et al., 2003, 2004; Patterson et al., 2007). The loss of knowledge on properties that lead healthy subjects to judge a picture as highly visually prototypical (i.e. distinctive properties) might impair the ability of semantic patients to perform a correct reality judgment.

3.6 CONCLUSION

The experiment described in the present chapter proves that patients affected by a perceptual or semantic degenerative disorder are impaired at OD task.

These findings provide support to the hypothesis that deciding whether an object or an animal is real or unreal requires both complex visual processing and conceptual knowledge (Hovius et al., 2003), and that the relative degree of involvement and interaction of visual and semantic abilities may differ through stimuli manipulation (Rogers et al., 2003). One limitation of our study could reside in the small number of patients included, and in their heterogeneity, despite our attempts to select cases showing the most similar neuropsychological profile and disease duration within each pathological group. When working with patients affected by neurodegenerative diseases, it is difficult to control for the clinical variability deriving from inter-individual differences in pathology progression (especially in semantic dementia) (Kertesz et al., 2010). It is certainly necessary to increase the sample size before drawing any general and definitive conclusion regarding OD performance under perceptual or semantic impairment.

CHAPTER 4

THE ROLE OF STRUCTURAL INFORMATION DURING WORD AND OBJECT RECOGNITION: EVIDENCE FROM REPETITION MASKED PRIMING

4.1 INTRODUCTION

The human visual system is able to perceive and identify objects on the order of few hundred milliseconds and in an effortless manner, but a complete understanding of the cognitive processes involved in object recognition has proven difficult.

In particular, as we reviewed in the previous chapters, the existence of a pre-semantic store merely devoted to the recognition of object structure and its independence from conceptual knowledge is still a matter of debate.

When processing a printed word, however, the presence of a level of analysis based on the orthographic appearance of words that acts as an interface between the sensory surface and conceptual knowledge is generally accepted.

The evidence that visual word recognition is guided by form-based orthographic representations rather than semantic factors is supported by the several masked priming studies (see Rastle & Davis, 2008 for a review) using very brief Stimulus Onset Asynchrony or SOA.

Masked priming is characterized by a rapid presentation of stimuli. Typically, the prime is presented very briefly and is immediately preceded and followed by a pattern mask and then by a subsequent target stimulus, presented in clear. The logic of this paradigm is that the presentation of the prime begins to activate the relative representation, but that the onset of the following mask stops the processing of the prime prior to the level of conscious identification; when presenting the target, it is then possible to probe for residual prime influence.

The typical behavioral effect is that target processing is facilitated when the prime and the target are identical or share certain features (repeated or related condition), compared to when they are different (unrelated condition).

This technique has proven to be particularly useful to help decompose the early stages of word processing (Forster & Davis, 1984; Rastle et al., 2004).

In particular, the manipulation of SOA or of the prime duration allows us to track the time-course with which different types of information become available during visual word recognition and lexical access.

Typically, it is difficult to detect semantic facilitation in lexical decision task when primes are forward masked and last as short as 50 ms (Rastle et al., 2000; Forster et al., 2003) even if few authors were able to find this type of effect (Williams, 1996; Perea & Gotor, 1997; Perea & Lupker, 2003; Perea et al., 2008; Feldman & Basnight-Brown, 2008; Marslen-Wilson et al., 2008; Kazanina, 2011).

However, evidence of semantic priming in a lexical decision task with subliminal primes seems to be elusive and affected by task-specific effects such as a post-lexical familiarity stage (Sereno, 1991), proportion of semantically related pairs (Bodner & Masson, 2003), type of relationship between prime and target (associative versus semantic) or morpho-orthographic facilitation of certain types of related pairs.

Facilitation in semantically related pairs can be found most strongly with prime durations that make prime clearly visible to the subject.

Some researchers have argued that the failure to detect a semantic priming effect could be interpreted as the proof that lexical entries capture orthomorphological structure (Rastle et al., 2004) and that the activation of meaning arises only later in the course of recognition.

Thus, a setting in which the prime lasts less than 50 ms seems to be ideal to show morpho-orthographic specific effects, irrespective to semantic factors (Forster & Azuma, 2000; Pastizzo & Feldman, 2002; Marslen-Wilson et al., 2008; Crepaldi et al., 2010; Kazanina, 2011: Amenta & Crepaldi, 2012).

But what about the application of this technique to the domain of object recognition?

A masked repetition priming effect with pictorial stimuli has not been systematically investigated in literature.

Data at our disposal come predominantly from the research group of Eddy, Holcomb and coworkers (Eddy et al., 2006, 2007, 2009, 2010 & 2011), who successfully combined event-related potentials (ERP) recordings and functional Magnetic Resonance with the masked priming paradigm to investigate the mechanisms involved in object recognition.

Briefly, in a series of experiments they recorded a pattern of ERP components that occur between 100 and 500 ms. The earliest of these ERP components, the N190/P190, is thought to reflect the activation of a perceptual feature representation. Once initial processing of features occurs, a more form-specific representation is activated, reflected by the N250 effect. The representation then becomes more abstract, activating a semantic, meaning based representation (N400).

In the fMRI study (Eddy et al., 2007) the authors demonstrated that automatic processing of rapidly and repeatedly presented complex objects was associated with effects in temporo-occipital regions, areas that were found to be sensitive to repetition priming also with masked words.

In 1998 Ferrand and co-workers were able to find a repetition priming effect in a picture naming task, employing, however, related words as primes.

Harris et al. (2008) found a repetition masked picture priming effect in a naming task as well, but only when primes were presented for as long as 70 milliseconds.

Finally, in Garcea et al.'s experiment (2012), a repetition priming effect with pictures also emerged in a categorization task. Prime discrimination data, however, suggested that prime pictures were partially visible to subjects, at least to allow them to make an accurate categorization decision that was significantly different from the chance level.

To our knowledge, an object decision task using a masked priming paradigm has never been implemented yet.

According to what reported above, if a lexical decision task with repetition masked priming is the election paradigm to investigate word recognition at the level of the Orthographic Input Lexicon, it would be stimulating to apply the same technique to study the time course of object recognition, with the intent to test the existence modular, independent status of the structural description system, i.e. of a non-semantic store of all existing visual objects (comparable to the orthographic lexicon in the word domain).

In the present experiment, we created two parallel tasks, one with a set of printed words and one with the corresponding pictures, and asked participants to perform a lexical decision or an object decision task, respectively.

Our main intent was to detect whether a repetition effect could emerge during an object decision task, since this has never been investigated in literature. If the effect occurs, we could infer that object recognition is driven from form-based representations, with no need to access semantic knowledge.

In addition to this, we were interested in exploring whether words and pictures share the same early recognition processing or not.

4.2 SUBJECTS, MATERIALS AND METHODS

4.2.1 Participants

Sixty students at the University of Milano Bicocca took part in the study. They were all skilled readers and native speakers of Italian, had normal or corrected-to-normal visual acuity, and had no history of neurological impairments and/or learning disabilities. The students were given course credits in exchange for their participation.

4.2.2 Materials

Two parallel sets of printed words and pictures were built to serve as experimental stimuli for this study. Both sets contained 27 targets, which refer to the same 27 objects, i.e., if the word casa (house) was selected as a target printed word, the corresponding picture of a house was also selected as a target picture. All target words were four letters in length. Pictures were black-on-white drawings and measured roughly 18 by 18 cm. These 27+27 targets were paired with either a repetition prime (the printed word/picture itself) or an unrelated prime. Unrelated prime words were all four letters in length. As for the targets, unrelated primes were also semantically identical in the word and picture sets, i.e., if the printed word casa (house) was paired with the printed word mano (hand) as unrelated prime, also the corresponding picture of a house had a picture of a hand as unrelated prime. This procedure allowed us to have experimental sets of printed words and pictures that are identical from a semantic point of view.

Repetition and unrelated primes in the printed word set were comparable for log frequency (1.38 ± .88 vs. 1.52 ± .75) and orthographic neighborhood size (8.07 ± 3.99 vs. 7.96 ± 3.74). They were also identical in length, as the whole set only included 4-letter words. Repetition and unrelated primes in the picture set were instead matched for picture typicality (.00 ± .43 vs. -.17 ± .60) and picture complexity (.03 ± .96 vs. -.16 ± 1.06) as measured by subjective ratings; these were asked from 16 university students at Milano Bicocca (who did not take part in the main experiment) using a 5-point scale .

Thirty pseudowords were created to serve as NO-response targets in the printed word set. These were all pronounceable, legal combinations of letters in Italian; in fact, they were obtained by changing one letter from existing words. Target nonwords were also comparable to target words for their orthographic neighborhood size (7.73 ± 3.39 vs. 8.07 ± 3.99), so as to prevent participants from responding YES or NO on the basis of the general word likeliness of the input stimulus. These target nonwords were paired with 30 related, one-letter-different prime words (e.g., sale, salt, primed the nonword sabe) and 30 unrelated, all-letter-different prime words (e.g., dono, gift, primed the nonword gera), so as to make the nonword target set completely symmetrical to the word target set. Overall, nonword-target primes were made as similar as possible to word-target primes for log frequency (1.63 ± .70 vs. 1.45 ± .81) and orthographic neighborhood size (8.02 ± 3.99 vs. 7.97 ± 3.46).

Thirty chimerical pictures were created as NO-response targets for the picture set. These were made up by blending the upper part of a picture (e.g., a camel) and the lower part of another picture (e.g., a donkey) in a way that guaranteed as much as possible the visual continuity of the contour. Pictures of both living and non-living objects were used to create the chimeras. The visual complexity of the chimeras was similar to that of the target pictures (.03 ± .96 vs. .23 ± .66). As for the printed word set, these chimerical pictures were paired with 30 related primes, i.e., the complete picture of either the lower or the upper part of the chimera (e.g., a camel served as a related prime for the camel+donkey chimera), and 30 unrelated primes, i.e., a picture of a visually and semantically unrelated object (e.g., a table served as an unrelated prime for the camel+donkey chimera). NO-trial primes were kept as similar as possible to YES-trial primes for their visual complexity (-.05 ± .63 vs. -.16 ± 1.06) and typicality (-.17 ± .60 vs. .07 ± .44). Stimuli for this experiment are contained in Appendix, page X.

4.2.3 Procedure

Participants were asked to carry out a YES-NO decision task based on whether the input stimulus was an existing word or an existing object. No mention was made about the presence of masked primes. Pictures and words were administered in separated sessions, whose order of presentation was counterbalanced across participants. Within these sessions, each participant saw each target (word or picture) only once, presented with either the related and unrelated primes; however, each participant was exposed to both related and unrelated primes along the course of the experiment. This was achieved thanks to a Latin square design with two rotations. Trial order was fully randomized within sessions. Testing always started with six example trials, after which participants were encouraged to ask for clarification in case of need. As a further control over outlier responses due to unfamiliarity with the task, each experimental session also started with four warm-up trials that were not included in the analyses.

Trial timeline was as follows, for both printed words and pictures. A visual mask – made up of a series of hashmarks for the word session, and of a black-and-white square grid (sized 15 by 15 cm) for the picture session – was presented at the centre of a computer screen for 500 ms. Immediately after its offset, the prime word/picture appeared on the screen for 42 ms. Prime words were presented in lowercase; prime pictures were instead shrank from their original size by a factor of 50% to 75% (Eddy & Holcomb, 2009). Then, the target word/picture appeared on the screen (in uppercase, for words, or in its full size, for pictures), and participants were asked to make their decisions through a two-button response box. The YES-response button was always controlled by the participant's dominant hand. Stimulus presentation and data recording were controlled by MatLab Psychtoolbox (MathWorks Corporation, 2011), which, thanks to some additional in-house software, guaranteed a ms control of the display.

After participants had completed both the word and the picture sessions, they came back to the lab (at least one week later) to be tested for their ability to perceive the prime pictures. This was done by presenting them with exactly the same picture stimuli as in the decision task, but this time telling them explicitly that a masked prime was always interleaved between the mask and the target, and asking them to judge whether primes and targets were the same picture. Participants were told that it would be very difficult to see the primes; however, they were encouraged to respond anyway, trusting their intuitions or, in case there was none, guessing. Participants' implicit perception was measured through a d-prime analysis. Stimulus presentation and response collection were carried out exactly as in the decision task described above.

4.3 RESULTS

Data were first inspected to identify outlying subjects, stimuli or individual data points. One participant was excluded because s/he performed worse than two SDs below the mean on both existing words and nonwords, and also had unusually low accuracy in the chimeric picture trials (s/he was barely above 50% correct). On the contrary, no target word/picture showed consistently low accuracy or slow responses. Trimming for individual data points was carried out separately for words and pictures; in both cases, we excluded RTs that overly deviated from the main distribution, i.e., lower than 350 ms or higher than 1400 ms for word trials, and lower than 400 ms or higher than 2000 ms for picture trials.

4.3.1 Printed Words

Mean response time was 592 ms in the unrelated condition (SD=126 ms) and 551 in the repetition-priming condition (SD=119 ms). A mixed-effects model with maximal random effect structure showed that this difference was significant (F[1, 1385]=67.28, $p<.001$). Mean accuracy was .96 in the unrelated condition (SD=.20) and .98 in the repetition priming condition (SD=.15): contrary to the RT analysis, this difference was proven non-significant by a logistic mixed-effects model with maximal random effect structure ($\chi2[1]=2.25$, p=.13).

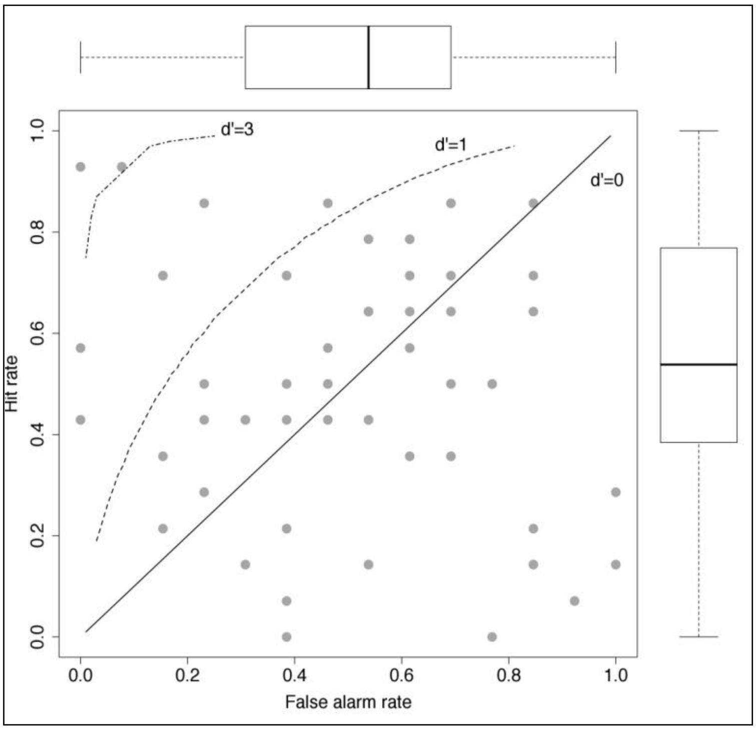
4.3.2 Pictures

Mean response time was virtually identical in the unrelated (875 ms, SD=303 ms) and repetition-priming conditions (874, SD=318 ms). Obviously, this difference was not significant (F[1, 1363]=.62, p=.37). Mean accuracy was .92 (SD=.27) in the unrelated condition and .94 (SD=.24) in the repetition priming condition. As for the RT analysis, this difference was not statistically significant ($\chi2[1]=.87$, p=.35) .

4.3.3 D-prime Analysis

Participants' performance in the identity decision task is illustrated in Figure 4.1.

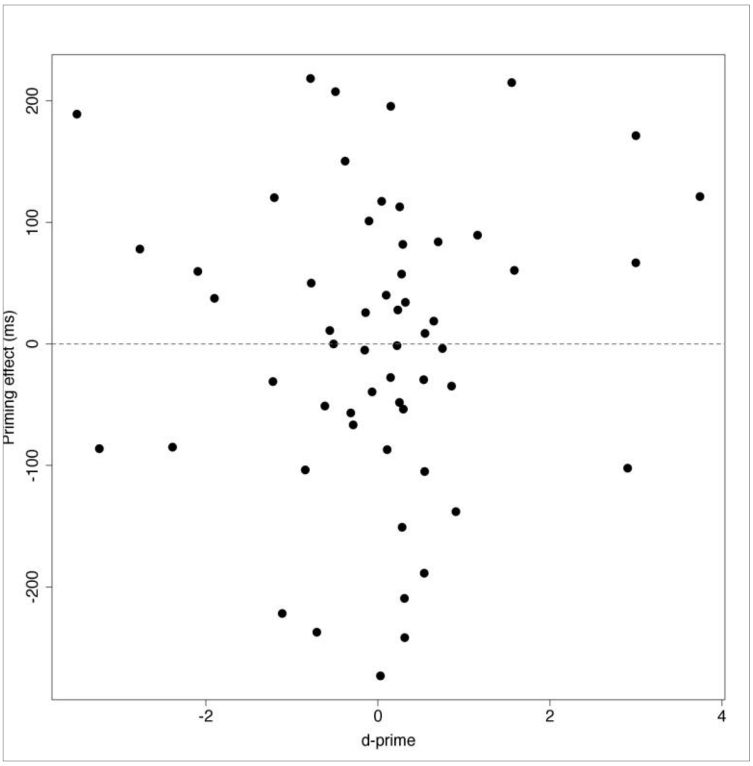
Fig. 4.1



The figure illustrates the participants' performance on the prime-target identity task. People are represented as points on a bi-dimensional space; the X axis reports on the false alarm rates and the Y axis on the hit rates. The flanker boxplots represent the unimodal distributions of these two variables. The lines on the plot are based on hypothetical data and identify d-prime areas.

As illustrated by the flanker boxplots, participants distributed along the hit-rate and false-alarm-rate axes roughly according to a normal distribution: on both indexes, most people performed around chance level and a few showed either a very good or a very bad performance. Thus, the vast majority of the participants had a d-prime index below 1, and only two of them proved to be consistently able to identify the prime picture. D-prime also turned out to be uncorrelated with repetition priming (see Figure 4.2).

Fig. 4.2

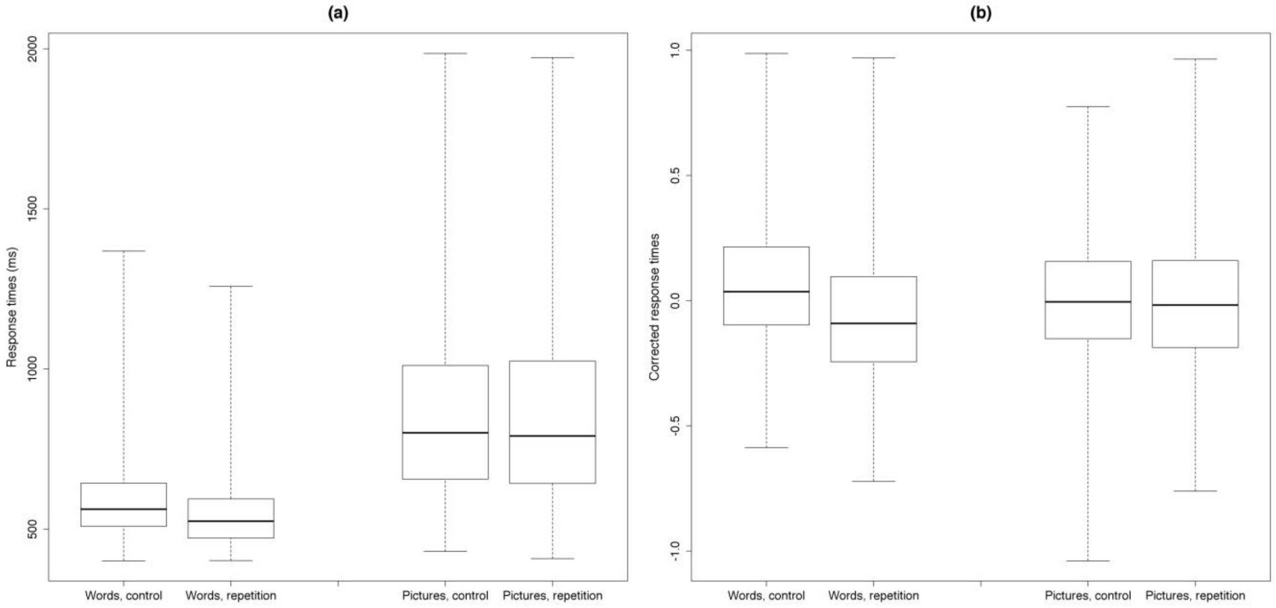


The figure illustrates the lack of correlation between d-prime (represented on the X axis) and repetition priming with pictures (represented on the Y axis as the difference between unrelated-prime and repetition-prime trials, i.e., facilitation goes negative). The Pearson correlation index is .06 .

4.3.4 Comparison between Words and Pictures

It is clear from what shown above that repetition priming emerged (as expected) with printed words, but there was no sign of an effect with pictures. However, we also sought to compare directly repetition priming in the two domains, so as to make sure that not only an effect is there among words and is not among pictures, but that the former is significantly larger than the latter. Carrying out this direct comparison, however, is not an easy task, mainly because response times were largely more variable for pictures than for printed words (see Figure 4.3(a)). This is only partially surprising as one considers that printed words and pictures are very different perceptual objects; despite the perfect semantic matching attained through the use of words and pictures that refer to the same objects, still pictures are visually more complex than words, are not made up of discrete sub-units (as for letters), vary much more than words in their different instantiations, etc. These differences reflect on the fact that response times on the two types of input are explained by very different variables (e.g., frequency for words and visual complexity for pictures). So, as an attempt to make response times comparable in the two domains, we partialled out the contribution of these variables before feeding the data into the main analysis. This was achieved by fitting RTs to words and pictures in separate mixed-effects models with different predictors – i.e., log frequency and orthographic neighborhood size for words, picture typicality and complexity for pictures – and using the residuals from these models in the main analysis. Because words and pictures were administered to participants in separate sessions, we also modelled trial-series effects by considering as additional independent variables trial position in the list, RT on the preceding item, and accuracy on the preceding item. This should guarantee control over context-dependent spurious variance (list effects). As illustrated in Figure 4.3(b), this procedure made in fact RTs to words and pictures more comparable (SD in the residuals was .25 for picture and .26 for words). The corrected data were analyzed through a classic two-way ANOVA (random effects were already captured by the mixed-effects models above) and revealed a strong overall effect of relatedness (F1 [1,58]=39.83, p<.001; F2[1,24]=68.05, p<.001), which is modulated by an interaction of relatedness by stimulus type (F1[1,58]=24.74, p<.001; F2[1,24]=42.89, p<.001).

Fig. 4.3



Box-plots representing condition-wise central tendency and variability in (a) uncorrected and (b) corrected response times.

4.4 DISCUSSION

Masked priming has been consistently reported in lexical decision experiments and was employed successfully to investigate the early stages of visual complex words recognition (Rastle & Davis, 2008). In particular, evidence for robust morphological and orthographic effects in the absence of any reliable semantic facilitation has led to the hypothesis that letter strings are first analyzed for their ortho-morphological structure (Forster et al., 1987; Rastle, Davis, & New, 2004) and that semantics come into play only later in the course of word recognition. Together with neuropsychological reports of patients with preserved formal analysis (see Coltheart, 2004, for a review), but no semantic processing, these findings have established the idea that word identification, i.e., understanding that a word is represented in our memory, is independent from (and precedes) word comprehension, i.e., understanding what a word means.

Because it is not clear whether these two processes exist as separate steps in visual object identification, the present study starts to explore the possibility that masked priming is applied fruitfully to that domain. The longer-term goal of this move is (a) to assess the existence of the structural description system, i.e. of a non-semantic store of all existing visual objects (comparable to the orthographic lexicon in the word domain) and, more generally, (b) to test whether words and pictures share the same early recognition processing. In this specific experiment, we preliminarily assessed whether masked priming emerges in object identification experiments and, if so, in which conditions. To this aim, we created a lexical and an object decision task employing two symmetrical sets of printed words and pictures, and administered them to sixty young normal subjects. Our results confirm masked repetition priming during lexical decision, but, most intriguingly, show no sign of priming with pictures.

Let us first consider this outcome in the context of what previous studies have found on masked priming with pictures (Harris et al., 2008; Eddy et al., 2006, 2007, 2009, 2010 &2011; Garcea et al., 2012).

Harris et al. (2008) employed a repetition priming paradigm in which the prime was presented for variable durations (ranging from 16 to 350 ms) and in various image-plane orientations (from 0° to 180°), and was followed by an upright target object which had to be named as rapidly as possible. They found that significant priming was obtained only for prime durations above 70 ms, but not for prime durations of 16 ms and 47 ms, and did not vary as a function of prime orientation. Importantly, the authors made the presence of the primes explicit to the participants (though instructing them not to pay attention to it). Despite the procedure clearly increased prime visibility, there is no priming at short SOAs.

Garcea and colleagues (2012) used a lateralized masked priming paradigm to test for a right visual field advantage in tool processing, and collected primes discrimination data after the completion of the experimental session (categorization task: “is the target an animal or a tool?”). They found a right visual field advantage in priming effects for tool but not for animal target, suggesting an overrepresentation of tool knowledge in the left hemisphere. They reported that primes were partially visible to the subjects, since they were able to make a categorization decision over the prime pictures (tool or animal?) with an accuracy of 68%. This suggests that Garcea et al.’s data are not really comparable to ours: the d-prime analysis illustrated in this chapter clearly shows that most subjects were at chance in saying whether primes and targets were identical, which is even arguably an easier task than Garcea et al.’s.

Finally, Eddy, Holcomb and coworkers (2006, 2007, 2009, 2010, 2011) carried out a series of ERP/fMRI experiments and consistently found repetition masked priming during a (semantic) categorization task. However, a number of methodological differences with our study suggest caution in the comparison. First, subjects were requested to perform the categorization task both with the prime or the target (“press a button when you see a food item, independently if in prime or in target position”), so they were clearly aware of the presence of the prime. (Nevertheless, the D’ analysis reported in those studies suggests that participants were not able to identify food objects in the prime position). Furthermore, the authors merely describe the neurophysiological results and never provide behavioral data, which clearly makes their results incomparable to ours. Another methodological issue that needs to be taken into consideration concerns the fact that we did not use a backward mask between the prime and the target, while a mask was always present in the experiments described above. We adopted the so-called “three-field paradigm” (forward mask – prime – target; Forster & Davis, 1984) because it is by far the most employed procedure in masked priming experiments with words, and we wanted to make the word and the object conditions as similar as possible. The inclusion of a backward mask could have led to an additional increase of prime visibility, which might explain why Eddy, Holcomb and colleagues consistently found masked priming.

Another fundamental difference between our study and the previous literature is the task employed: previous studies always called upon semantics (in different ways), while we used a reality decision task, which arguably can be carried out successfully without any help from semantics, at least as long as word stimuli are involved.

The fact that priming is very sensitive to the experimental task is becoming more and more established within the literature on visual word recognition (Norris & Kinoshita, 2008; Kinoshita & Norris, 2012). The most striking evidence comes from the observation that only word targets show priming in the lexical decision task (Foster, 1998), but both words and non-words do in a same-different task (where participants have to say whether the target string is the same as a reference string shown earlier; Norris & Kinoshita, 2008), or that semantic priming effects are generally weak in a lexical decision task (Rastle et al., 2000), but are robust in a semantic categorization task (Dehaene et al., 1998; Kunde et al., 2003). Bueno and Frenck-Mestre (2008) also demonstrated that semantic priming effects with masked primes can be detected with shorter SOA in semantic categorization than in lexical decision tasks. So, it seems that different tasks tap into different stages of the word recognition process, which is why the same perceptual event (masking) may give rise to different phenomena. Of course, this is likely to be true for object identification too.

Our study is thus the first to address masked priming in object identification using a non-semantic task, which yields two fundamental advantages when one wants to assess the existence of a non-semantic store of all existing visual objects, i.e., (a) it takes emphasis out from semantics, thus making less likely that the effect is driven by that level of analysis and (b) it makes object masked priming more comparable to an established benchmark, that is, word masked priming. In the light of this second aspect, we did not only use a reality decision task, but also adopted the same SOA with both pictures and words, and used words and drawing referring to the exact same objects, thus ruling out any possible semantic mismatch. Despite all these considerations, words display their usual masked repetition priming, while objects clearly do not.

Obviously, there might be several reasons behind this fact. Our analyses rules out already three of these options. First, the lack of masked priming with objects does not depend on the fact that response times in this domain are very variable; even when RTs with words and objects were made equally variable through linear transformations, words benefited significantly more than objects from the previous masked presentation of the target. Second, the fact that object and word processing depend on different variables (and thus arguably tap on different parts of the visual system) is not sufficient to explain their difference; when the effects of frequency and orthographic neighborhood size were partialled out from word RTs, and picture typicality and complexity were partialled out from objects RTs, masked priming did emerge with words, but not with objects. Third, masked priming with objects was shown NOT to depend on participants' ability to process the prime deeply enough in 42 ms, or at least to their ability to identify the prime as the same picture as the target; in fact, d-prime in a prime-target same-different task does not correlate with priming.

All these considerations suggest that words and objects trigger different processing steps early after they come into contact with our perceptual system.

Because objects are clearly more complex visual entities than words, it remains possible that words and pictures share the same early recognition processing, but that pictures require a longer time to be processed. In this perspective, 42 ms may perhaps be sufficient to get enough information from words (whatever this information is) to generate masked priming, while this would not be possible with objects. The finding that our participants took more time to make their reality decision on pictures than on words would support this hypothesis. In order to assess this possibility, we are now collecting data from an Incremental Masked Priming experiment, in which we utilized the same set of stimuli used in the present study, but manipulated primes duration (12, 36, 48 and 59 ms) and collected d-prime data in a prime-target same-different task on both words and pictures.

Finally, it could be that the visual information immediately available from pictures and words is quite different: for words, for example, visual-orthographic information is an obvious gateway to access the mental lexicon, and semantic information is available only afterwards. On the contrary, with pictures, semantic information can be retrieved directly from visual cues (such in the case of animals). Word recognition might thus rely more on "structural information" for words, while object recognition might need to interact with semantic knowledge.

It is worth noting that this account would be at odds with some data in the masked priming literature, coming in particular from fMRI studies. Eddy et al. (2007), for instance, showed clear effects of repetition masked priming with pictures within the ventral-temporal processing stream, up to the posterior fusiform gyrus. These areas overlap to those activated when we have to process a visual word (Dehaene et al., 2004). In this regard, Dehaene and colleagues (2004, 2005) offered a hierarchical account of visual word recognition that predicts that the earliest steps in morphological processing are carried out by letter combination detectors in the fusiform gyrus, which would be sensitive to the orthographic form of frequently occurring morphemic units. Similar results were also provided by Devlin et al. (2004; see Rastle & Davis, 2008 for a review of the neural bases of morpho-orthographic decomposition).

CHAPTER 5

CONCLUSION

The experiments conducted in the present dissertation address the following question: can object recognition be achieved on the basis of structural features alone or does conceptual knowledge contribute to a competent recognition of it?

The rationale was suggested starting from a current debate in the neuropsychological literature. Theories of visual object recognition typically describe the Structural Description System, which is the locus where episodic structural features of stimuli are compared with the stored visual representation of known objects, as being functionally independent from Semantic Memory (Marr, 1982; Riddoch & Humphreys, 1987; Sheridan & Humphreys, 1993; Hillis & Caramazza, 1995).

These theories are mainly based on the finding that some agnostic patients are still able to decide about the reality of an object (assessed through an Object Decision task) despite being unable to access any semantic knowledge about it.

More recently, the evidence that patients affected by Semantic Dementia may show impaired performance at object decision has challenged the functional and neuroanatomical separation of the structural description system from semantic memory (Hodges et al., 1994; Hovius et al., 2003; Rogers et al., 2003, 2004; Patterson et al., 2006; Zannino et al., 2011), suggesting that recognizing an object is not simply the result of matching it to a structural description, but is the result of an interactive perceptual and semantic processing.

5.1 STUDY 1

To address the issue concerning the role of semantic knowledge in object recognition, we created a novel object decision task where we systematically manipulated the structural, visual and semantic characteristics of the stimuli, in order to isolate the variables that may influence object recognition in healthy individuals, and administered it to a sample of twenty participants. Their task was to decide whether a picture represents a real or an unreal artefact object or animal. More specifically, in the unreal category we included objects in which we manipulated the overall proportion (Metrical items) or in which we rearranged the spatial relationship between object parts (Scrambled items), Kroll & Potter pictures and chimeras. Within the category of chimeras we varied the semantic relatedness and, only for objects, the manipulation similarity between the two parts composing the chimera, so to obtain Unrelated, Semantically Related and Same Manipulation chimeras. Metrical and Scrambled objects allow us to investigate whether the analysis at Structural Description level is based on feature processing or on whole-object processing, while the variation of the conceptual relatedness between chimeric parts could help us at disentangling the role of semantic memory during object decision. Our prediction was that if reality decision may be performed with no access to conceptual knowledge, no difference will emerge between related and unrelated chimeras. On the contrary, the evidence of a worst performance on related with respect to unrelated chimeras would support an independence between the two systems.

Consistently with data reported in the previous literature on normal subjects (Lloyd-Jones & Humphreys, 1997; Gerlach et al. 1999, 2001, 2006; Kahlaoui et al., 2007), our participants obtained faster reaction times (RTs) and a better accuracy with the objects' category with respect to the animals one. The most widely accepted hypothesis is that animals are more difficult to differentiate than artefacts because they are more visually similar and share more common parts with other members of their category. Consequently, a larger range of related representations are activated in visual long-term memory and compete during stimulus selection (Lloyd-Jones & Humphreys, 1997; Humhreys & Forde 2001; Gerlach et al, 2009).

As regards the visual and semantic manipulation of unreal stimuli, participants obtained the best performance with Kroll & Potter pictures, and performed almost flawlessly also with Metrical, Scrambled and Unrelated Chimeras. The accuracy was, instead, significantly lower (and RTs significantly longer) for Semantically Related and Same Manipulation chimeras, with no significant difference between these two categories.

Our results suggest that Kroll & Potter pictures were extremely easy to reject, possibly because they are processed as non-objects, with no need to access the structural description system to perform the reality judgment: only when the stimuli are "object-like", they have to access the SDS and undergo further processing (analysis of spatial features, analysis of the spatial relationship among the object parts, and matching of the shape with previously stored representations).

The evidence of a good performance with Metrical and Scrambled stimuli, confirms that young adults may process object as a whole and not by single-features analysis, supporting the data previously reported in literature by Davidoff & Roberson (2002).

More interesting, as regard the comparison between Unrelated and Related chimeras, our findings clearly suggest that manipulation of the semantic characteristics of stimuli influences the performance on a realty decision task.

We thus provide further support to the idea that the more interaction is required between perceptual and semantic systems (as in the related chimeras), the more difficult it is to perform an efficacious object recognition.

In conclusion, the study showed that the Object Decision task cannot be considered a purely structural or pre-semantic task; by contrast, our findings are in favour of an interaction between structural description system and semantic memory.

5.2 STUDY 2

In this second study, we aimed at investigating what happens to the OD performance when perceptual abilities or semantic knowledge are impaired. We administered our experimental OD task to eight patients with a progressive impairment of visuo-perceptual abilities, who showed difficulties in tasks investigating the early analysis of objects shapes (such as figure-ground discrimination), and to seven patients who presented with a moderate and progressive impairment of semantic knowledge, but showed spared abilities in early visual processing. Four semantic cases met diagnostic criteria for Semantic Dementia (Neary et al., 1998), one for Fronto-Temporal Lobar Degeneration (Neary et al., 1998), two for Mild Cognitive Impairment (Winblad et al., 2004) restricted to the semantic domain.

Six out of eight perceptual patients were diagnosed with Posterior Cortical Atrophy (McMonagle et al., 2006) and two with Cortico-Basal Syndrome (Boeve et al., 2003).

Ten control subjects, matched for age and education, were recruited. Controls were screened to rule out neurological or major psychiatric illness.

All patients were referrals to the Centre for Cognitive Disorders of the San Gerardo Hospital, Monza, where they underwent clinical and cognitive assessment by a senior neurologist and a neuropsychologist. Structural brain imaging and/or functional neuroimaging data (PET/SPECT) were also collected for each participant.

The findings of the study show that patients affected by progressive degeneration of semantic or perceptual functions are impaired at OD task.

As regards posterior atrophies, to our knowledge, this is the first time that an OD task composed by different types of unreal stimuli (including chimeras) has been employed to detect an object recognition impairment in PCA and CBS patients.

On the other hand, results deriving from our semantic patients corroborate previous data of an Object Decision deficit in SD patients as reported in literature (Hodges et al., 1994; Hovius et al., 2003; Rogers et al., 2003, 2004; Patterson et al., 2006; Zannino et al., 2011).

This evidence provides support to the hypothesis that deciding whether an object or an animal is real or unreal requires both complex visual processing and some degree of conceptual knowledge (Hovius et al., 2003), and that the relative degree of involvement and interaction of visual and semantic abilities can be varied through stimuli manipulation (Rogers et al., 2003).

5.3 STUDY 3

Repetition Masked Priming is a useful paradigm that has been employed successfully in lexical decision experiments to investigate the early stages of visual complex words recognition (Rastle & Davis, 2008).

More specifically, evidence for robust morphological and orthographic effects in the absence of any reliable semantic facilitation has led to the hypothesis that recognizing a word (by matching it to a representation in our memory at the level of the Orthographic Input Lexicon) is independent from (and precedes) word comprehension, i.e., understanding what a word means.

As regards pictorial stimuli, the presence of a system merely devoted to the analysis of the structural information (i.e. Structural Description System), irrespective to semantic factors, is still a matter of debate.

Moreover, the application of the Masked Priming technique to pictures has not been systematically investigated in literature. To our knowledge, few authors were able to find a repetition effect with pictures during a naming or a categorization task (Ferrand et al., 1998; Harris et al., 2008; Garcea et al., 2012; Eddy et al., 2006, 2007,2009, 2011), but an object decision task using a masked priming paradigm has never been implemented yet.

Hence, the aim of the present experiment was twofold: (a) to assess the existence of a non-semantic store of all perceived visual images of objects (comparable to the orthographic lexicon in the word domain) and, more generally, (b) to test whether words and pictures share the same early recognition processing.

We thus created two parallel tasks, one with a set of printed words and one with the matched pictures and we asked our participants to carry out a YES-NO decision task based on whether the input stimulus was an existing word or an existing object. No mention was made about the presence of masked primes. Pictures and words were administered in separated sessions, whose order of presentation was counterbalanced across participants.

After participants had completed both the word and the picture sessions, they came back to be tested for their ability to perceive the prime pictures.

The results showed that repetition priming emerged (as expected) with printed words, but there was no effect with pictures. The D’ analysis revealed that participants performed at chance level when asked to identify the prime, indicating that it was not consciously processed while carrying out the tasks.

We identified two possible explanations for these findings: on one hand, data argue against the existence of a store in which an analysis of purely pictorial structural information is carried out, as it happen for words. Word recognition might thus rely more on "structural information", while object recognition might need to interact more with semantic knowledge.

However, it remains possible that words and pictures share a same early processing, but that pictures require a longer time to be treated. In this case, our prime duration (42 ms) may be sufficient to get enough information from words to generate masked priming, while this would not be possible with objects. In order to disentangle this possibility, we are now implementing an Incremental Masked Priming experiment in which we are employing the same set of stimuli as in the present study, but with different prime durations (12, 36, 48 and 59 ms).

In conclusion, the evidence arising from the three studies described in this dissertation can lead us to affirm that, in normal conditions, object decision is not obtained on the basis of structural features only. Conversely, it seems that an interaction between structural and semantic knowledge is necessary to perform an efficient object reality decision.

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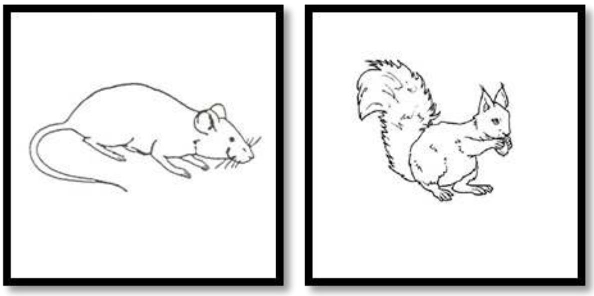
APPENDIX

CHAPTER 2

Example of stimuli employed in the Object Decision task

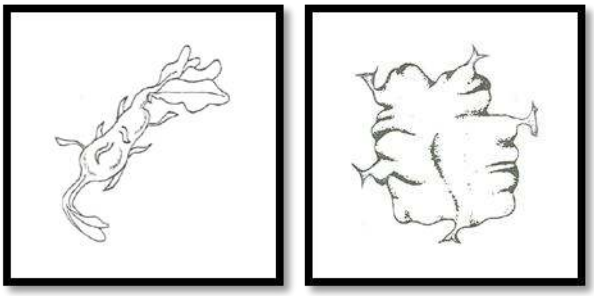
Animal Category

Real Animals:

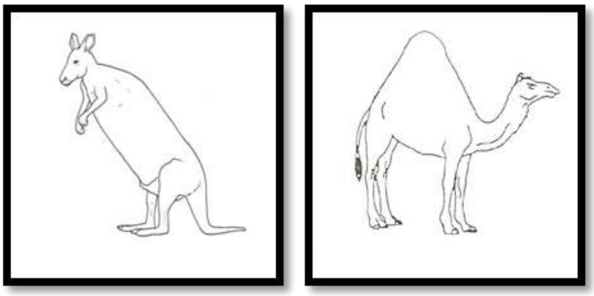


Unreal Animals:

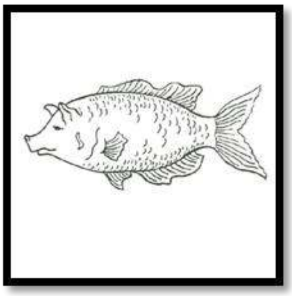
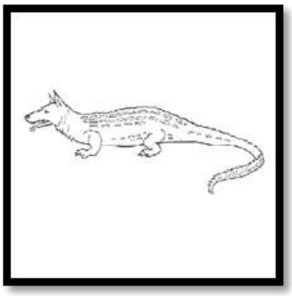
- Kroll & Potter Pictures



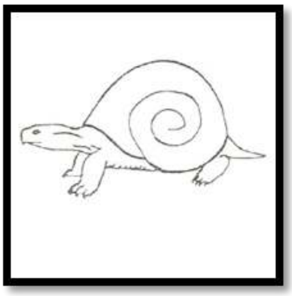
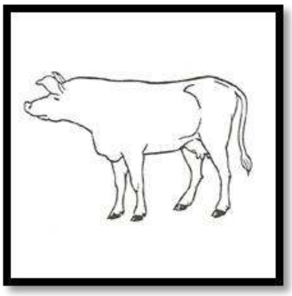
- Animals with Metrical Alterations



- Unrelated Chimeras

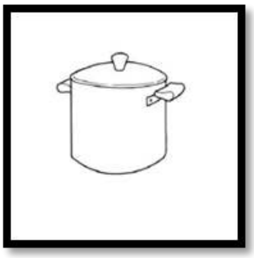



- Semantically Related Chimeras

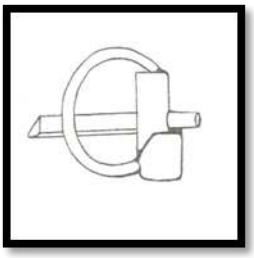
Objects Category

Real Objects:



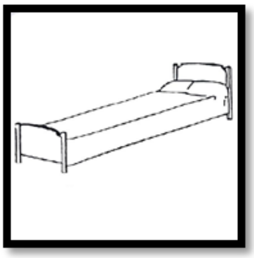

Unreal Objects:

- Kroll & Potter Pictures



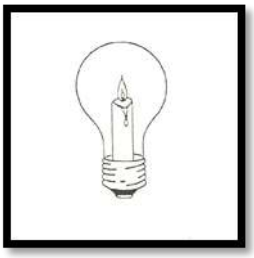

- Scrambled Objects

- Objects with Metrical Alterations

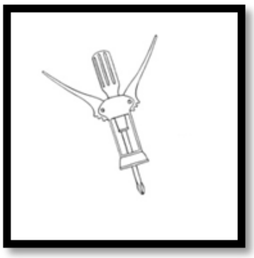


- Unrelated Chimeras

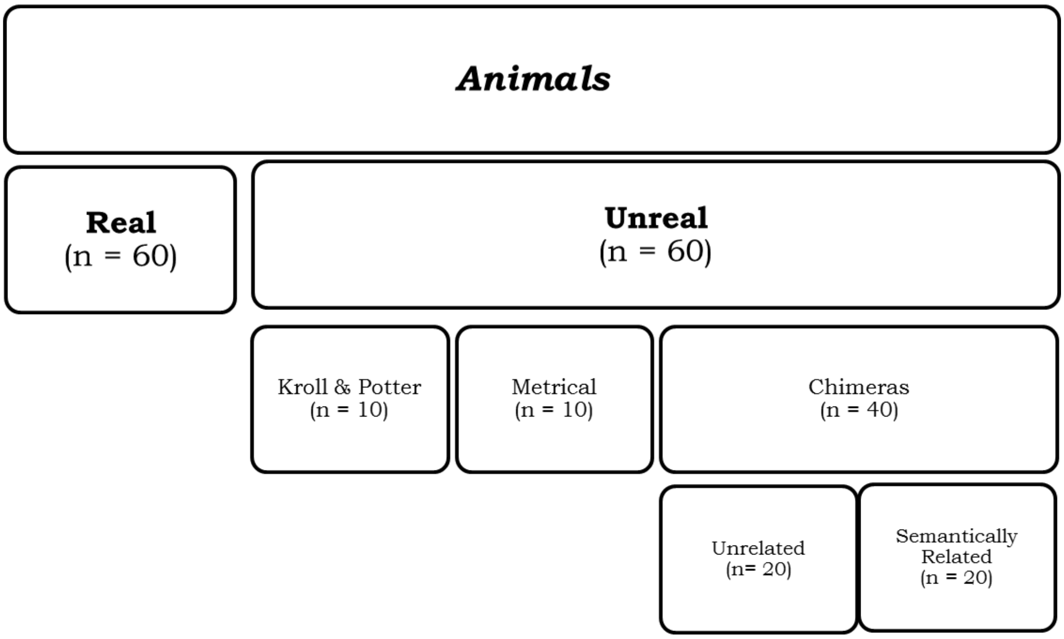
- Semantically Related Chimeras

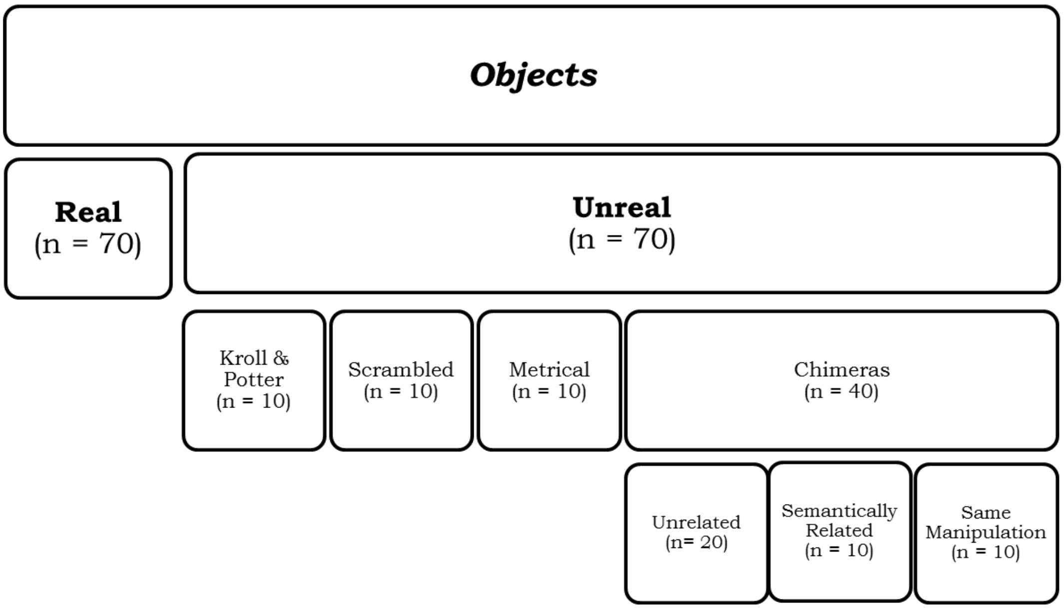


- Same Manipulation Chimeras



Schematic View of the Final Stimuli Included in the Task





CHAPTER 3

DESCRIPTION OF PATIENTS

Patients with semantic memory disorders

1) Patient RL

RL, a right-handed, 81 year old man with five years of education, underwent formal neuropsychological assessment for possible initial dementia. His cognitive profile was characterised by mild deficits at semantic verbal fluency, confrontation naming, verbal and visual associative knowledge, and executive functions.

An FDG brain PET scan showed moderate bilateral fronto-temporal hypometabolism.

Criteria for Semantic Dementia (Neary et al., 1998) were met.

2) Patient GN

GN, a right-handed, 58 year old woman with five years of education, had a four year history of mild cognitive impairment prodromal of semantic dementia.

At her fourth neuropsychological formal assessment she was included in the present study. At that time she showed mild frontal disturbances and moderate degree semantic impairment mostly affecting picture naming, verbal and visual associative knowledge, category verbal fluency.

At MRI and FDG-PET scans she had evidence of predominantly left anterior temporal damage.

Criteria for Semantic Dementia (Neary et al., 1998) were met.

3) Patient BC

BC is a right-handed, 74 year old woman with five years of formal education. At referral her relatives were complaining of forgetfulness and behavioural disorders (euphoria, irritability and apathy). The neuropsychological assessment showed mild deficits at confrontation naming, category fluency and episodic memory.

At retest episodic memory deficits were stable, while semantic and executive functions were slightly worsened.

SPECT scan demonstrated moderate right temporal and mild bilateral frontal hypoperfusion.

A diagnosis of Fronto-Temporal Dementia was made (Neary et al., 1998).

4) Patient IV

IV, a left-handed, 82 year old man with eight years of education, was referrred to our memory clinic because of forgetfulness and difficulties in recognizing familiar faces. Neuropsychological examination did not evidence relevant cognitive deficits but a borderline score at a famous faces recognition and identification task (Test “Grazia Neri”, Bizzozzero et al., 2005).

Brain TC scan showed mild bilateral temporal atrophy. At FDG-PET scan he had evidence of hypometabolism at the temporal poles, and in the left parietal region and cingulate gyrus.

At retest, performed one year and a half later, he presented with abnormal scores at pictures naming, visual associative memory, identification of famous faces and verbal episodic memory.

Diagnosis was MCI (Winblad et al., 2004) restricted to the semantic domain.

5) Patient OM

OM, a right-handed, 77 year old woman with five years of formal education, had a two year history of memory complaints, anomias and difficulties in the identification of famous faces.

At her first evaluation she showed a mild deficit in tests of recognition of public figures (Test “Grazia Neri”; Bizzozzero et al., 2005) and executive functions, while scores obtained at category fluency and picture naming tasks were borderline.

MR imaging showed bilateral temporo-mesial atrophy (more evident at the level of sylvian fissures and temporal horns of lateral ventricles). Frontal, temporal and parietal hypometabolism was evident at FDG-PET.

At follow-up she had worsen globally, but executive functions and semantic memory were still proportionally more impaired.

A diagnosis of Semantic Dementia (Neary et al., 1998) was made.

6) Patient TT

TT, a right-handed, 80 year old men with six years of education, complained of episodic memory deficits, spatial disorientation and anomias. He underwent four cognitive assessments in six years’ time. When he was first administered the Object Decision Task, his cognitive profile was characterized by mild deficits of word retrieval and episodic long-term memory.

MR imaging showed generalised, symmetrical atrophy of mild degree, and modest vascular burden. FDG-PET scan demonstrated generalised left hypometabolism.

At retest, one year later, he showed visual semantic memory impairment and a stable deficit in picture naming, while he performed better in the Rey Auditory Verbal Learning Task.

Diagnosis was MCI (Winblad et al., 2004) restricted to the semantic domain.

7) Patient AU

AU, a right-handed 56 year old woman with 13 years of education, had been complaining of memory deficits and behavioural disturbances for one year. At formal testing she showed moderate verbal and visual episodic and semantic memory impairment, and a severe deficit at picture naming.

At MR imaging she had evidence of bilateral temporal poles atrophy. FDG-PET scan showed predominantly left temporo-mesial and temporo-parietal hypometabolism.
Criteria for Semantic Dementia (Neary et al., 1998) were met.

Patients with visuo-perceptual impairment

1) Patient RE
RE, a right-handed, 68 year old man with eight years of education, had been complaining of memory deficits and word finding difficulties for three years. His cognitive profile was characterized by mild deficits at picture naming and delayed recall of Rey's words list.
An FDG-PET scan showed hypometabolism in the left temporo-occipital and parietal regions.
At retest, one year later, deficits in long-term memory, visuo-spatial abilities, picture naming and visual associative memory were present.
Criteria for Posterior Cortical Atrophy (temporo-occipital variant - Mc Monagle et al., 2006) were met.

2) Patient IB
IB, a 68 year old woman with eight years of formal education, underwent a first cognitive assessment that showed a severe deficit in visuo-construction and perceptual skills and a milder impairment of linguistic and frontal functions. Asymmetric ideomotor apraxia was also present.
At retest, two years later, the cognitive profile worsened, and ideomotor apraxia had become bilateral. The Object Decision Task was administered at this time.
MR imaging showed widespread atrophy. FDG-PET scan demonstrated bilateral parietal and temporo-occipital hypometabolism. At 123I-Ioflupane SPET there was evidence of mild decrease of tracer uptake, i.e. dopaminergic degeneration, in the left putamen.
Criteria for Corticobasal Syndrome (Boeve et al., 2003) were met.

3) Patient EL
EL, a 61 year old man with five years of education, was referred for memory deficits and writing difficulties. The neuropsychological assessment demonstrated a predominant impairment of left parietal functions (presence of Gerstmann's syndrome and bilateral ideo-motor apraxia). At retest, one year later, here was a global cognitive worsening, involving especially praxic and visuo-spatial functions.

MR imaging showed generalised, symmetrical atrophy of mild degree, and modest vascular burden. FDG-PET scan demonstrated predominantly left parietal plus bilateral temporal hypometabolism. At 123I-Ioflupane SPET there was evidence of a borderline decrease of tracer uptake in both putamen nuclei.

A diagnosis of Posterior Cortical Atrophy (McMonagle et al., 2006) was made.

4) Patient AR

AR, a right-handed, 66 year old woman with five years of education, underwent formal testing because of difficulties in executing fine movements, especially with her left hand. The cognitive profile was characterized by mild to moderate visuo-spatial dysfunction, left ideomotor apraxia and mild executive deficits.

At MRI she had evidence of generalised, moderate atrophy involving the corpus callosum, and modest vascular burden. FDG-PET scan showed widespread hypometabolism, more evident in the right temporal and parietal regions. 123I-Ioflupane SPET was normal.

A diagnosis of Posterior Cortical Atrophy (McMonagle et al., 2006) was made.

5) Patient GC

GC, a right-handed, 76 year old woman with eight years of education, was referred to our memory clinic as she complained of memory deficits, anomias and anxiety. The neuropsychological assessment showed a cognitive profile characterized by moderate visuo-constructive deficits and asymmetric limb apraxia.

MR imaging showed generalised atrophy and mild vascular burden. FDG-PET scan demonstrated a predominantly right temporal and parietal hypometabolism.

A tentative diagnosis of Corticobasal Syndrome (Boeve et al., 2003) was made.

6) Patient AI

AI, a right-handed, 75 year old man with 13 years of education, underwent neuropsychological assessment due to the presence of memory deficits and spatial disorientation. The cognitive profile was characterized by multiple deficits, more evident in the visuo-perceptual, praxic and episodic memory domains.

At MR imaging there was evidence of predominantly posterior brain atrophy and of mild vascular burden. FDG-PET scan demonstrated moderate bilateral temporal, temporo-parietal and parietal hypometabolism.

Criteria for Posterior Cortical Atrophy (biparietal variant) (McMonagle et al. 2006) were met.

7) Patient GB

GB, a right-handed, 60 year old woman with eight years of education, had a two year history of memory complaints. The neuropsychological assessment highlighted moderate visuo-perceptual deficits and milder episodic memory impairment.

MR imaging and 123I-Ioflupane SPET were normal. FDG-PET scan showed predominantly left temporo-occipital and parietal hypometabolism.

A diagnosis of Posterior Cortical Atrophy (occipito-temporal variant) (McMonagle et al., 2006) was made.

8) Patient VB

VB, a right-handed, 51 year old man with eight years of education, was referred for ‘difficulties in reading the clock’ and acalculia. Formal testing showed mild but widespread impairment involving predominantly parietal functions.

At MR imaging there was evidence of mild posterior atrophy. FDG-PET scan demonstrated hypometabolism in the right temporo-parietal region and, to a lesser extent, in left frontal and parietal regions.

Criteria for Posterior Cortical Atrophy (biparietal variant) (McMonagle et al., 2006) were met.

CHAPTER 4

Stimuli used in the Experiment

Target and Prime Words / Pictures

Word / Picture	Related Prime	Unrelated Prime
FICO	fico	sega
TOPO	topo	mela
CANE	cane	viso
ROSA	rosa	luna
NASO	naso	vite
PIPA	pipa	more
DITO	dito	nave
OSSO	osso	pera
PUMA	puma	taxi
DADO	dado	pala
RANA	rana	cubo
SOLE	sole	nota
ARPA	arpa	remo
BICI	bici	ramo
CASA	casa	mano
UOVO	uovo	faro
COMÒ	comò	orca
GUFO	gufo	orma
LUPO	lupo	mago
PINO	pino	alce
MOTO	moto	onda
NIDO	nido	orso
NODO	nodo	tela
FOCA	foca	cucu
MULO	mulo	fata
VASO	vaso	toro
IENA	iena	arco

Target Non-Words and Prime Words

Non-Word	Related Prime	Unrelated Prime
BENO	seno	puro
SABE	sale	tiro
TULA	tuta	seme
NISO	riso	buco
FOSE	fase	cura
REVA	riva	solo
LEBO	sebo	diga
FIRO	filo	neve
TICO	tifo	resa
GERA	sera	dono
SEPE	pepe	mito
DENE	rene	baco
RICO	rito	seta
PEVO	pelo	duca
RUGE	rupe	timo
MUDO	muso	ripa
DERA	cera	lino
TOGE	doge	pupo
SAGO	saga	feto
LERA	lira	data
COBO	lobo	ruga
TILA	fila	cena
DISA	risa	fune
DALE	dame	cono
LIVO	lido	toga
CETA	ceto	foro
BUGA	fuga	vino
LUBA	tuba	foce
SICO	sito	mina
NALI	pali	cute

Target Chimeras and Prime Pictures

Chimera	Related Prime	Unrelated Prime
cammello+asino	cammello	tavolo
grillo+pescespada	grillo	divano
volpe+uccello	volpe	cacciavite
ippopotamo+tricheco	tricheco	caffettiera
avvoltoio+pesce	avvoltoio	cesto
volpedeserto+canguro	canguro	barca
canarino+scoiattolo	canarino	gruccia
zucca+ananas	ananas	lavagna
ciliegia+aglio	ciliegia	fucile
fragola+fungo	fungo	letto
banana+melanzana	melanzana	pentola
anatra+delfino	anatra	mattarello
elefante+lama	elefante	padella
squalo+coccodrillo	squalo	telefono
clessidra+calice	clessidra	lumaca
forchetta+manichino	forchetta	pinguino
svegia+ruota	sveglia	pipistrello
fiasco+lampada	lampada	capra
mappamondo+orologio	orologio	panda
forcone+imbuto	forcone	gatto
occhiali+mezzaluna	occhiali	rondine
mongolfiera+carota	mongolfiera	cavalluccio
scarpa+maschera	maschera	gorilla
appendino+matita	appendino	coccinella
forbici+molletta	molletta	pecora
spada+chitarra	spada	tartaruga
grano+piccone	grano	tigre
racchetta+birillo	birillo	castoro
gelato+bottiglia	gelato	biscia
lente+frusta	lente	cavallo