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# Lexical-semantic deficits in processing food and non-food items

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ABSTRACT

The study of category specific deficits in brain-damaged patients has been instrumental in explaining how knowledge about different types of objects is organized in the brain. Much of this research focused on testing putative semantic sensory/functional subsystems that could explain the observed dissociations in performance between living things (e.g., animals and fruits/vegetables) and non-living things (e.g., tools). As neuropsychological patterns that did not fit the original living/non-living distinction were observed, an alternative organization of semantic memory in domains constrained by evolutionary pressure was hypothesized. However, the category of food, that contains both living-natural items, such as an apple, and nonliving-manufactured items as in the case of a hamburger, has never been systematically investigated. As such, food category could turn out to be very useful to test whether the brain organizes the knowledge about food in sensory/functional subsystems, in a specific domain, or whether both approaches might need to be integrated. In the present study we tested the ability of patients with Alzheimer dementia (AD) and with Primary Progressive Aphasias (PPA) as well as healthy controls to perform a confrontation naming task, a categorization task, and a comprehension of edible (natural and manufactured food) and non edible items (tools and non-edible natural things) task (Tasks 1–3). The same photographs of natural and manufactured food were presented together with a description of food's sensory or functional property that could be either congruent or incongruent with that particular food (Task 4). Patients were overall less accurate than healthy individuals, and PPA patients were generally more impaired than AD patients, especially on the naming task. Food tended to be processed better than non-food in two out of three tasks (categorization and comprehension tasks). Patient groups showed no difference in naming food and non-food items, while controls were more accurate with non-food than food (controlling for the linguistic variables and calorie content). AD patients named manufactured food more accurately than natural food (with PPA and controls showing no difference). Recognition of food and, to some extent, of manufactured food seems to be more resilient to brain damage, possibly by virtue of its survival relevance. Furthermore, on Task 4 patients showed an advantage for the sensory-natural pairs over sensory-manufactured combination. Overall, findings do not fit an existing model of semantic memory and suggest that properties intrinsic to the food items (such as the level of transformation and the calorie content) or even to the participants like the Body Mass Index (as shown in another study reviewed here) should be considered.



## 1. Introduction

How concepts are organized in the mind/brain has long been debated in cognitive neuroscience. A considerable enhancement in this field coincided with the systematic observation of category-specific deficits in patients with brain damage. The neuropsychological research program has, in turn, generated several hypotheses that differ for the type of principle that is held to be responsible for the organization of our semantic knowledge in the brain. In the following we will address the question of how the category 'food' is represented in the lexical-semantic system. After introducing the main extant hypotheses, we will then present our study on how patients with Alzheimer dementia (AD) and with Primary Progressive Aphasias (PPA) process lexical-semantic information about food and non-food stimuli.

## 2. The organization of the semantic system

After early anecdotal reports (Hecaen & de Ajuriaguerra, 1956; Mccrae & Trolle, 1956; Nielsen, 1946), Warrington and Shallice

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(1984) systematically investigated the ability of four patients with herpes simplex encephalitis (HSE) to identify objects from various categories. The authors demonstrated that patients were disproportionally impaired at confrontation naming and at understanding names of fruits/vegetables and animals (or living things) but showed normal processing of tools, vehicles, toys and other inanimate things (or nonliving things). In striking contrast with this pattern, patient V.E.R., suffering from global dysphasia after a stroke, showed a reduced auditory-visual comprehension for objects but not for living things (Warrington & McCarthy, 1983). These dissociative patterns led Shallice, Warrington and coworkers (Borgo & Shallice, 2001, 2003; Warrington & McCarthy, 1987; Warrington & Shallice, 1984) to hypothesize the existence of two putative modality-specific semantic subsystems, one representing sensory properties of objects, such as color, texture or taste, and the other representing functional properties, such as their prototypical functions (the Sensory-Functional Hypothesis, SFH). Thus, according to this view, recognizing living things (including edible and nonedible substances, drinkable and non-drinkable liquids, and materials, see Borgo & Shallice, 2001, 2003) critically depends on a putative subsystem specialized for sensory information, while processing nonliving things critically depends on a subsystem for functional properties. The category-specific deficits would arise as a consequence of damage to either one of the semantic subsystems. It has also been proposed that category-specific deficits for living things may arise at pre-semantic level of processing, caused by the perceptual crowding among their structural descriptions (Humphreys & Forde, 2001; Humphreys, Riddoch, & Quinlan, 1988).

However, the SFH has been criticized for not being able to explain all the observed patters of spared and impaired performance (see Capitani, Laiacona, Mahon, & Caramazza, 2003).[1] First, the SFH theory does not predict that a subsystem might break down in subcategories and therefore cannot account for the observed dissociations, for instance, between animals and plant life within the sensory subsystem (e.g., Blundo, Ricci, & Miller, 2006; Caramazza & Shelton, 1998; Hart, Berndt, & Caramazza, 1985; Laiacona, Barbarotto, & Capitani, 2005; Samson & Pillon, 2003). Second, according to the SFH, while damage to the sensory subsystem should impair the processing of perceptual attributes of living things, damage to the functional subsystem should impair the processing of functional features of nonliving things. However, a disproportionately impaired recognition of either living things or nonliving things has not always occurred with a loss of visual/perceptual attributes or functional/associative attributes respectively (Miceli et al., 2000; Silveri & Gainotti, 1988).

To account for these findings not easily explainable with the SFH, Caramazza and collaborators put forward the domain-specific knowledge hypothesis (DSH; Caramazza & Mahon, 2006; Caramazza & Shelton, 1998; Mahon & Caramazza, 2009, 2011). According to the DSH, the evolutionary pressure has imposed an innate organization of the conceptual knowledge by domains such as animals, plants, conspecifics and tools, turning object recognition in a more efficient process. Thus the DSH supports the organization of knowledge into categories that play an essential role in the survival of our species. The category-specific deficits observed most likely occur at the semantic level and might reverberate on the lexicon.

## 3. Food category

As for other categories, brain damage is expected to lead to disproportionately or selectively food recognition as well. The way in which the knowledge about food breaks down in brain-damaged patients could explain how food concepts might be represented in the brain and, possibly, how they support our eating behavior and choices. By its nature, the food category seems very well suited to test whether SFH can account for possible category specific-deficits affecting food (see Capitani et al., 2003, for a similar argument), in that food category contains *both* natural items (e.g., apple, banana, tomato, etc.) and manufactured items (e.g., pasta, hamburger, ice cream, etc.).

There are three other reasons, all biologically grounded, why we think this distinction is relevant. *First*, natural food and manufactured food supply differential energetic values, with manufactured food, in general, providing higher energy values (e.g., Carmody, Weintraub, & Wrangham, 2011). In particular, it has been argued that the Paleolithic hominids, since they discovered the use for cooking, around 300,000–400,000 yrs. ago, began to prefer this method to others because the energetic advantage it offered. This preference seems to be conserved over evolutionary history. To model food preferences in hominids, Wobber, Hare, and Wrangham (2008) had great apes taste different plant and animal foods to establish whether they preferred food items raw or cooked. The authors observed that several populations of captive apes often preferred their food cooked, and thus concluded that hominids would likewise have spontaneously preferred cooked food to raw. In a different study investigating the effects of unprocessed, pounded, and/or cooked diets on body mass and food preference in mice (*Mus musculus*), Carmody et al. (2011) found that the animals on cooked starch and meat diets showed raises (or at least minor losses) in body mass and, compared with naïve rodents, preferred cooked starch. *Second*, thermal and nonthermal techniques are applied to food in all cultures also because they increase its palatability and edibility (Carmody & Wrangham, 2009, for a review). *Third*, some foods that are poisonous or toxic if eaten raw, thus this discrimination is potentially relevant for health. *Lastly*, cooking dramatically reduces the likelihood of infection, again providing an advantage to individuals able to discriminate raw from cooked food.

Different predictions about food recognition can be drawn from existing neuropsychological theories. According to the SFH, damage to a putative sensory subsystem would lead to a deficit for living things including natural food (fruits/vegetables), for recognition of all these items is expected to rely more on perceptual features; in contrast, recognition of nonliving things and manufactured food should result unaffected. Damage to a putative functional subsystem would give rise to the opposite side of the dissociation, with patients showing a deficit for non-living things as well as manufactured food, as recognition of all these items relies more on specific functions and actions they require. As far as the DSH is concerned, it is not necessary to predict a breakdown in performance between natural food and manufactured food: evolution shaped food category as a whole given its importance for the survival of our species. However, the analysis of the existing neuropsychological studies is not sufficient to clarify how food concepts are represented in the mind/brain. In the published studies food stimuli used were too few, they were often not distinguished in natural and manufactured, and were not matched for relevant variables (Rumiati & Foroni, 2016).

## 4. The study

The main aim of the present study was to evaluate lexical-semantic processes involved in food recognition and understanding. We explored this issue at the group level in patients with Alzheimer dementia (AD), patients with Primary Progressive Aphasias (PPA), and healthy controls. The main reason for choosing these two pathological populations was that they are expected to differ

[1] The discussion of all possible inconsistencies is beyond the scope of the present study.