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Semantic feature degradation and naming performance. Evidence from neurodegenerative disorders

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ABSTRACT

The failure to name an object in Alzheimer's disease (AD) and in the semantic variant of the primary progressive aphasia (sv-PPA) has been generally attributed to semantic memory loss, with a progressive degradation of semantic features. Not all features, however, may have the same relevance in picture naming. We analyzed the relationship between picture naming performance and the loss of semantic features in patients with AD with or without naming impairment, with sv-PPA and in matched controls, assessing the role of distinctiveness, semantic relevance and feature type (sensorial versus non-sensorial) with a sentence verification task.

The results showed that distinctive features with high values of semantic relevance were lost only in all patients with naming impairment. The performance on the sensorial distinctive features with high relevance was the best predictor of naming performance only in sv-PPA, while no difference between sensorial and non-sensorial features was found in AD patients.

1. Introduction

Defective object naming can be due to the impairment of multiple cognitive processes. One crucial component is semantic memory, a system composed by the general and personal knowledge of an object, including the semantic features necessary to identify the object and to distinguish it from similar concepts. For example, in order to identify and name the picture of a kangaroo, the feature "has pouch" is crucial to distinguish it from similar other animals. Other semantic features, such as "uses tail to keep balance", while specific for the kangaroo, may not be generally required for identification. The classical model of Miller and Johnson-Laird (1976) posited the existence of an identification mechanism, selecting the semantic features necessary to uniquely identify and consequently name a picture. Although several subsequent models implicitly or explicitly ascribe different importance to semantic features for concept identification and naming (Chertkow & Bub, 1990; Hodges, Patterson, Graham, & Dawson, 1996; Whatmough & Chertkow, 2002; Sartori and Lombardi, 2004; DeLeon et al., 2007; Garrard, Lambon Ralph, Patterson, Pratt, & Hodges, 2005), what is the kind of semantic information necessary to name pictures has not been clearly identified.

Important evidence of the role of semantic memory in naming abilities comes from patients with neurodegenerative diseases. Semantic memory impairment is a defining feature of semantic dementia (SD), and is also frequently reported in the early stage of Alzheimer's disease (AD). In these patients however the nature of the semantic memory impairment is still debated (Chertkow, Bub, & Seidenberg, 1989; Chertkow et al., 1994; Hodges, Salmon, & Butters, 1992; Martin, 1992; Nebes, Brady, & Huff, 1989; Nebes, 1992; Ober & Shenaut, 1988).

Several authors have proposed that the failure to name an object in both AD and SD patients reflects a similar underlying degradation of semantic knowledge, showing a relation between naming performance and the status of semantic memory (Chertkow & Bub, 1990; Hodges, Graham, & Patterson, 1995; Hodges et al., 1996; Warrington, 1975). Longitudinal studies investigating types of errors in picture naming showed the presence of

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progressively more generic responses in both AD and SD (Gonnerman, Aronoff, Almor, Kempler, & Andersen, 2004, Hodges et al., 1995; Paganelli, Vigliocco, Vinson, Siri, & Cappa, 2003; Warrington, 1975). As the disease progresses, errors progress from semantic paraphasias – coordinate error – (horse for zebra), to superordinate (animal for zebra), to an inability to name the item, demonstrating the preservation of top-down hierarchically organized semantic knowledge and suggesting that specific features are the most vulnerable (Hodges et al., 1995).

Conversely, a normal performance on a picture naming task does not guarantee by itself that semantic representations remain intact (Chertkow & Bub, 1990; Joubert et al., 2010), suggesting that only a part of semantic knowledge is necessary for naming. Chertkow and colleagues (Chertkow and Bub, 1990; Whatmough and Chertkow, 2002) showed that AD patients, who were able to name a picture of a zebra, correctly answered to questions that uniquely identified the animal (e.g., Is the zebra striped?). However, at the same time these patients answered incorrectly to many basic questions concerning the animal (“Do zebras meat eat?”, “Do they live in Africa?”). In contrast, only when patients could not correctly answer to identification questions concerning an animal, they could not name the picture of the same animal.

Several other studies proposed that not all features are equally important to naming (Hodges et al., 1996; Marques, 2002; Moss, Tyler, Durrant-Peatfield, & Bunn, 1998; Whatmough & Chertkow, 2002) and tried to identify the nature of the most important ones, considering different types of knowledge. Semantic features may be categorized as referring to sensorial (visual, tactile, etc.) and non-sensorial information (including functional, associative and encyclopaedic features). Features can also vary along a shared–distinctive continuum, with distinctive features, occurring in only one or few concepts, allowing to differentiate between closely related concepts, typically members of the same semantic category, i.e., “has pouch” for kangaroo. Shared features, like “has legs”, occur in a very large number of concepts. The peculiar role of distinctive features as compared to shared features has been proposed by several authors, as they are essential in order to discriminate between concepts belonging to the same semantic category, and consequently crucial in tasks like picture naming (Moss, Tyler, & Devlin, 2002; Tyler, Moss, Durrant-Peatfield, & Levy, 2000). In both AD and SD patients, several studies using different tasks showed a similar pattern of progressive deterioration of semantic memory, in which distinctive attributes are lost first, shared ones later (Alathari, Trinh Ngo, & Dopkins, 2004; Duarte, Marquié, Marquié, Terrier, & Ousset, 2009; Garrard et al., 2005; Giffard et al., 2001, 2002; Laisney et al., 2011; Perri, Zannino, Caltagirone, & Carlesimo, 2011; Perri, Zannino, Caltagirone, & Carlesimo, 2013; Rogers et al., 2004; Warrington, 1975). It has been suggested that semantic errors at picture naming can be due to an early loss of distinctive features and to the preservation of shared ones, leading to ambiguous semantic representations. This relation, however, has been directly investigated only by few studies in AD patients (Duarte et al., 2009; Garrard et al., 2005).

Garrard et al. (2005) analyzed the role of distinctiveness and of the sensory and non-sensory features on the picture naming performance. AD patients were administered a picture naming task and a probed test of semantic attribute knowledge, where all the feature dimensions, as well as the production frequency (dominance) and distinctiveness, were derived from a previous database. They documented a closer relationship of performance in picture naming with visual rather than functional features, suggesting a greater importance of visual knowledge for naming an object. In addition, differently from their expectations, they showed no clear evidence that distinctive features are significantly more often associated with correct naming responses than shared information. They attributed these results to an insufficient statistical power, and to a numerical superiority of shared attributes. However, it is important to note here that not all the distinctive features have the same importance for identifying an object. Semantic relevance can also be considered to play an important role in naming (see Sartori, Lombardi, & Mattiuzzi, 2005). The distinctive features *has pouch* can be considered to be of high relevance, in that it is present for only one concept and many subjects use it to define a kangaroo. In contrast, *has legs* has a lower value of semantic relevance in that it is present in many concepts and few subjects use it to define a kangaroo. The same feature can have different values of relevance for different concepts (dependent from the number of subjects who list that feature for different concepts) (Sartori and Lombardi, 2004).

In order to better understand the difference between distinctiveness and semantic relevance, consider the two features “uses tail to keep balance” and “has pouch”. Both are distinctive features, in that they are reported only for the kangaroo. However, the first is listed by 3 subjects, the second by 20 (example taken form features norms taken from Catricalà et al. (2013)). The different importance of the two features is captured by relevance, rather than by distinctiveness. Semantic features with high relevance are those which are useful for distinguishing the target concept from similar concepts. Garrard et al. (2005) used all the distinctive features present in their database, without discriminating patients' performance between distinctive features with high and low dominance (namely, for different values of semantic relevance). This could be the reason behind the lack of a relationship between naming and distinctive features reported in their study.

The aim of this study was to investigate the relation between picture naming performance and the status of semantic memory at feature level in patients with different neurodegenerative pathologies and with different degree of picture naming impairments. In particular, we were interested in individuating the features necessary for correct naming. A picture naming task and a sentence-verification task were administered to a group of AD (classified in 2 sub-groups on the base of naming impairment) and sv-PPA. We considered different parameters (distinctiveness, semantic relevance) and type (sensorial and non-sensorial) of features, in order to identify which are the features most correlated with a naming deficit. Considering the evidences reported above, namely that not all the features are essential for correct naming, and that not all the distinctive features have the same importance to the task of identifying a concept, we expected distinctive features with high level of relevance (i.e., “has pouch” for kangaroo), to be critically important to successful name production. On the other hand features with a low level of relevance (“uses tail to keep balance” for kangaroo) may be lost in patients without naming impairment, as not immediately important for naming. We suppose that both sensorial and non-sensorial features may or not be crucial, based on their contribution to the meaning of the concept and a major or selective impairment for one with respect to the other type is dependent upon the topological distribution of atrophy for the specific pathology. Although both AD and sv-PPA patients may be impaired on naming tests showing similarities with regards to the loss of the distinctive features with a high level of relevance, it is reasonable to think that the groundings of the underlying semantic impairment may differ between the two groups, as the pattern of cortical atrophy is different. In sv-PPA naming deficits are due to a semantic memory impairment and associated with the prominent atrophy in the anterior temporal lobe, with a further involvement of more posterior temporal areas, supporting a greater degradation of sensorial (visual) features (Hoffman, Jones, & Lambon Ralph, 2012). In AD the nature of naming impairment is more debated, as it may be due to diminished stores of semantic information, impaired access to relatively intact stores of semantic representations, or to a combination of both. In