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When the zebra loses its stripes but is still in the savannah: Results from a semantic priming paradigm in semantic dementia

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ABSTRACT

Studies using semantic priming paradigms to measure the integrity of the features underlying concepts in semantic dementia (SD) reported differential impairment, in that functional features appeared to be more robust to brain damage than other features, such as perceptual ones. However, these prior studies were single case reports and the inclusion of too many heterogeneous features under the "functional features" heading casts doubts on their apparent preservation. To verify the robustness of functional features compared with perceptual ones, we carried out a group study where we deliberately restricted the exploration of semantic features to two clearly defined types of attribute: visuoperceptual ("visual") versus contextual–functional ("contextual"). We administered an implicit lexical-decision priming task to 8 SD patients and 31 healthy matched controls, at baseline. Four of the patients underwent a follow-up assessment at one year. For controls, we found a significant priming effect in the visual condition, but not in the contextual one, whereas the SD group exhibited the reverse pattern of performances. The follow-up data provided evidence of the robustness of the dissociation between priming performances in the two attribute conditions. The fact that a particular priming effect was observed in the SD patients but not in controls could be regarded as a sign of semantic disequilibrium. Since perceptual features have been shown to be a core determinant of similarity-based/taxonomic relationships, whereas complementary-based/thematic processing relies mainly on contextual relationships, we interpreted our findings in terms of the differential recruitment of one of the two systems of semantic relationships (taxonomic vs. thematic). Moreover, these two distinct and parallel systems have previously been reported to coexist – and compete – in healthy adults. We thus argue that controls automatically drew on similarity-based/taxonomic relationships, leading to a significant priming effect for visual features but not for contextual ones. By contrast, their impaired perceptual features forced the SD patients to resort to the system of thematic relationships.

1. Introduction

Semantic dementia (SD) is a rare subtype of frontotemporal lobar degeneration (Moreaud et al., 2008; Neary et al., 1998; Snowden, Goulding, & Neary, 1989). It arises out of temporal lobe atrophy, often bilateral but predominantly on the left side (Chan et al., 2001; Hodges, Patterson, Oxbury, & Funnell, 1992). SD is characterized by a gradual and a selective loss of conceptual knowledge, resulting in limited vocabulary in speech, poor comprehension, and deficits in the identification of objects and persons in different input modalities (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000; Luzzi et al., 2007; Snowden, Thompson, & Neary, 2004). While conceptual knowledge distressingly collapses as the disease progresses, language remains fluent and well-structured, without any phonological or grammatical errors, and only subtle abnormalities in the syntactic structure of SD patients' speech have been reported (Meteyard & Patterson, 2009). General intellectual ability, day-to-day memory and visuoperceptual abilities remain relatively spared. Activities of daily living are also relatively preserved until the later stages of the disease.

Semantic breakdown in SD is currently presented as "a selective impairment to semantic abilities that affects all modalities of

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reception and expression, for all kinds of concepts, more or less equally, and it is the consequence of relatively focal brain lesions" (Patterson, Nestor, & Rogers, 2007, p. 978). Although SD patients often exhibit a significant deterioration in the attributes of underlying concepts, Lambon Ralph, Patterson, Garrard, and Hodges (2003) used explicit semantic tasks (naming to description, description-to-picture matching, and verbal definitions) to show that functional/associative features fare better than sensory/perceptual ones.

Patients' performances on explicit semantic tasks could, however, potentially be biased by the activation of intentional and deliberate processes (Ober, 2002), thus increasing the probability of impairment due to extra-semantic processes. For this reason, it is advisable to use an implicit assessment when exploring the organization of conceptual knowledge. Semantic priming paradigms are one of the methods that are currently used to measure the integrity of semantic knowledge. Priming tasks reduce intentional processes and promote automatic access to semantic knowledge. Operationalized in a lexical-decision task, these implicit paradigms require participants to decide as quickly and as accurately as possible whether a letter string constitutes a real word. This word is preceded by the brief presentation of a prime word that is either related or unrelated semantically to the target word. Based on spreading activation theory, and its assumptions of an interconnected network of concepts (Collins & Loftus, 1975), these paradigms trigger the automatic activation of all the concepts connected to the prime word, such that short reaction times (RTs) can be assumed to reflect closeness between concepts (i.e., between the prime and target words) in the semantic network.

To our knowledge, only five studies have used priming paradigms, operationalized in implicit lexical-decision tasks to measure the integrity of semantic knowledge in SD patients (Laisney et al., 2011; Moss, Tyler, Patterson, & Hodges, 1995a; Nakamura, Nakanishi, Hamanaka, Nakaaki, & Yoshida, 2000; Rogers & Friedman, 2008; Tyler & Moss, 1998). In most of these studies, the primed monitoring tasks explored different kinds of semantic relations between concepts, comparing category superordinates/coordinates with unspecified attributes or functional features within the same experimental design.

Disturbed priming effects were reported when the implicit assessment focused on category superordinate (e.g., "*walnut*" priming "*wood*") and/or coordinate relationships (e.g., "*cherry*" priming "*apple*"). Three studies failed to demonstrate any priming effect at all in these conditions (Moss et al., 1995a; Nakamura et al., 2000; Rogers & Friedman, 2008), while Laisney et al. (2011) observed an abnormally increased priming effect in the two category-coordinate conditions (distant coordinate relationships: "*whale*" priming "shark"; and close coordinate relationships: "bee" priming "wasp"). Moreover, the magnitude of this hyperpriming effect was greater for close coordinate conditions than for distant ones. This last result was underpinned by the extinction of the semantic priming effect in the distinctive attribute condition in the SD group (e.g., "*zebra*" priming "*stripes*"). In accordance with Chertkow, Bub, and Seidenberg (1989), Laisney et al. (2011) interpreted this hyperpriming effect as the result of disturbed semantic knowledge. More specifically, they regarded it as reflecting the loss of distinctive attributes. Since the prime and the target could no longer be distinguished, an over-priming condition was generated (Giffard et al., 2001, 2002). In a longitudinal study in Alzheimer's disease (AD), Giffard et al. (2002) found that the hyperpriming effect was purely transient, corresponding to a narrow window of opportunity as the semantic system continued to deteriorate. The extensive semantic knowledge loss subsequently spread to every feature of the concepts, with the result that priming effects could no longer be observed in any of the conditions.

Priming studies assessing attribute integrity in SD patients have yielded rather conflicting results, leading to divergent conclusions regarding the deterioration in semantic features. While two earlier case reports (Moss et al., 1995a; Tyler & Moss, 1998) had highlighted a surprising preservation of the priming effect in the functional attribute condition in two SD patients (PP and AM), two later studies (Laisney et al., 2011; Rogers & Friedman, 2008) failed to find any priming effect in attribute conditions in SD groups. These apparently conflicting results may stem from the fact that these two recent studies were not designed to compare the integrity of different kinds of features. Moreover, Rogers and Friedman (2008) did not provide any details about the types of features they used. Studies making a more fine-grained distinction between different types of attributes have reported differential priming patterns. In the first case study (Moss et al., 1995a), PP exhibited spared semantic priming for functional features (e.g., "*shampoo*" priming "*hair*"), but no priming effect for category-coordinate relationships (e.g., "*cat*" priming "*dog*"). In the second case study, Tyler and Moss (1998) assessed the integrity of two kinds of features (functional: "*crocodile*" priming "*river*"; and perceptual: "*crocodile*" priming "*green*") and two category relations (superordinate: "*crocodile*" priming "*animal*"; and coordinate: "*crocodile*" priming "*alligator*"). AM underwent the same testing session three times over an 18-month period. On initial testing, AM showed normal priming effects in the two attribute conditions, but no priming in the category conditions. At the 11-month follow up, functional attributes continued to prime robustly, but priming was no longer observed in the other conditions, including perceptual attributes.

Nonetheless, various methodological shortcomings may partially account for the longer preservation of priming effects in the functional condition. One could argue that the features included under the heading of so-called "functional properties" in the experiments conducted by Moss et al. (1995a) and Tyler and Moss (1998) were heterogeneous. In the former, Moss et al. (1995a) combined two kinds of relationships in the functional condition: a set of priming pairs where the prime consisted in something that was used to perform an action on the target (e.g., "*broom*" – "*floor*") and another set of priming pairs sharing contextual relationships (i.e., frequent co-occurrence, with the target referring to a typical component of the event or script evoked by the prime: "*theater*" – "*play*"). In Tyler and Moss's (1998) priming task, this heterogeneity was even more striking since a careful examination of the kinds of features included in the functional condition highlighted quite different kinds of relationships between the primes and the targets. Under the same « functional » label, the primes and the targets could in fact share "used to perform an action" relationships (e.g., "*desk*" priming "*work*"), contextual relationships (e.g., "*crocodile*" priming "*river*"), as well as word pairs containing strong lexical associations, i.e. relationships between two concepts in idiomatic expressions, proverbs and quotations (e.g., "*fox*" priming "*sly*"). Such heterogeneity makes it hard to draw inferences about the status of so-called "functional" features. Indeed, Rogers and Friedman (2008) have claimed that the lexical associations involve nonsemantic processing. In their semantic priming task, they included this kind of relationship as a control condition (e.g., "*needle*" priming "*haystack*") and observed a normal priming effect in SD patients. Moreover, "used to perform an action" relationships could, to some extent, implicate the visual object affordances (i.e., mechanisms that support object use directly from visual and/or tactile input) which were isolated by Hodges, Bozeat, Lambon Ralph, Patterson, and Spatt (2000) as one of the factors accounting for spared abilities to use objects in SD. We could thus ascribe the spared and robust priming effect previously observed in SD patients to the excessively broad types of attributes included