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Research report

Semantic word category processing in semantic dementia and posterior cortical atrophy

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ABSTRACT

There is general agreement that perisylvian language cortex plays a major role in lexical and semantic processing; but the contribution of additional, more widespread, brain areas in the processing of different semantic word categories remains controversial. We investigated word processing in two groups of patients whose neurodegenerative diseases preferentially affect specific parts of the brain, to determine whether their performance would vary as a function of semantic categories proposed to recruit those brain regions. Cohorts with (i) Semantic Dementia (SD), who have anterior temporal-lobe atrophy, and (ii) Posterior Cortical Atrophy (PCA), who have predominantly parieto-occipital atrophy, performed a lexical decision test on words from five different lexico-semantic categories: colour (e.g., *yellow*), form (*oval*), number (*seven*), spatial prepositions (*under*) and function words (*also*). Sets of pseudoword foils matched the target words in length and bi-/tri-gram frequency. Word-frequency was matched between the two visual word categories (colour and form) and across the three other categories (number, prepositions, and function words). Age-matched healthy individuals served as controls. Although broad word processing deficits were apparent in both patient groups, the deficit was strongest for colour words in SD and for spatial prepositions in PCA. The patterns of performance on the lexical decision task demonstrate (a) general lexicosemantic processing deficits in both groups, though more prominent in SD

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than in PCA, and (b) differential involvement of anterior-temporal and posterior-parietal cortex in the processing of specific semantic categories of words.

1. Introduction

The brain regions involved in language processing seem to extend well beyond the classical Broca (inferior frontal) and Wernicke (superior temporal) areas of the dominant hemisphere. Furthermore, evidence from functional neuroimaging indicates that, in addition to regions responsive to words in general, different brain regions are engaged during the processing of various word classes, with activated areas depending in part on the type of meaning. For example, words pertaining to colours and colour knowledge have been found to activate regions of the temporal lobe anterior to colour perception areas in posterior temporal cortex (Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995; Simmons et al., 2007), whereas words related to object shape engage more posterior-temporal regions (Moscoso Del Prado Martin, Hauk, & Pulvermüller, 2006; Pulvermüller & Hauk, 2006). Even more specifically, words referring to actions typically performed using the face (e.g., *chew*), arm (*clap*) and leg (*jump*) have been shown to activate the very same areas in the motor and premotor cortex that control movement of those specific body parts (Grisoni, Dreyer, & Pulvermuller, 2016; Hauk, Johnsrude, & Pulvermüller, 2004; Hauk, Shtyrov, & Pulvermüller, 2008; Kemmerer, 2015; Shtyrov, Butorina, Nikolaeva, & Stroganova, 2014; Shtyrov, Hauk, & Pulvermüller, 2004). Activation of sensori-specific brain regions in semantic processing has been documented for odour-related words such as *jasmine* (Gonzalez et al., 2006), words semantically related to sounds such as *telephone* (Kiefer, Sim, Herrnberger, Grothe, & Hoenig, 2008), and taste-related words such as *salt* (Barros-Loscertales et al., 2012). These and similar results showing category-specific activation patterns have led to the suggestion that different sets of cortical areas contribute differentially to conceptual semantic processing (for review see Pulvermüller, 1999; Pulvermüller, 2013).

If language processing relies on distributed semantic circuits that extend into sensory and motor regions, then lesions in and close to these modality-preferential areas should have differential effects on the processing of different word categories. Indeed, over the past three decades, numerous patient studies have reported such category-specific impairments. Double dissociations have been found in the processing of animals versus tools and living versus non-living things (e.g., Gainotti, 2004; Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984). Investigations of noun and verb processing have reported that the two word categories are differentially affected following lesions due to stroke or neurodegenerative disease (Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Boulenger et al., 2008; Cotelli et al., 2006; Damasio & Tranel, 1993; Kemmerer, Rudrauf, Manzel, & Tranel, 2012; Neininger & Pulvermüller, 2003). For instance, patients with motor neuron disease (MND), a neurodegenerative condition predominantly affecting the sensorimotor system, were consistently more impaired on action verbs than object nouns in picture naming and comprehension tasks (Bak et al., 2001); and patients with Parkinson's disease, a condition primarily characterised by motor disorders, had deficits in processing action verbs compared to concrete nouns (Boulenger et al., 2008).

The conclusions of these imaging and neuropsychological studies have not, however, been universally endorsed. For example, since object nouns and action verbs differ not only in semantic but also in lexical and morpho-syntactic characteristics (Schnur et al., 2009; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011), differences in processing the two word categories may not provide clear evidence for category-specific semantic networks (Bird, Lambon Ralph, Patterson, & Hodges, 2000; Mahon & Caramazza, 2008). Furthermore, some studies have not controlled for critical stimulus variables such as word length, frequency, imageability or orthographic/phonological patterns. For example, because many nouns are object names, they tend to be more imageable and visually-related than verbs. Verbs, on the other hand, typically have higher word stem frequency than nouns. Also, nouns and verbs could in theory activate different cortical areas due to their phonological makeup (see de Zubicaray, Arciuli, & McMahon, 2013 for an analysis of the latter in this context), given that phonological features seem to relate to different cortical loci (Evans & Davis, 2015; Pulvermüller et al., 2006; Schomers, Kirilina, Weigand, Bajbouj, & Pulvermüller, 2015). Controlling for such psycholinguistic stimulus variables is vital since syntactic, lexical and semantic features, and even aspects of surface structure, all contribute to distinctions between nouns and verbs (Bird et al., 2000; Funnell & Sheridan, 1992; Pulvermüller, 1999).

When such psycholinguistic variables were tightly controlled in imaging studies, the specific activation of modality preferential areas during language processing was confirmed for well-matched semantic symbol types, such as words related to colour and form or the body-part specific subtypes of action words (Grisoni et al., 2016; Kiefer & Pulvermüller, 2012). However, the activation of an area during symbol processing does not uniquely identify the role of these activated regions in semantic processing. Even unambiguous functional magnetic resonance imaging (fMRI) results do not establish a necessary role of action-perception systems for semantic processing. Differential deficits across categories associated with specific lesion sites may, at least in some researchers' views, constitute more compelling evidence for the necessity of such contributions to semantic processing. The current study assessed semantic word category processing in