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Semantic dementia and the left and right temporal lobes

Julie S. Snowden [a,b,*], Jennifer M. Harris [a,b], Jennifer C. Thompson [a,b], Christopher Kobylecki [a,b], Matthew Jones [a,b], Anna M. Richardson [a,b] and David Neary [a]

[a] Cerebral Function Unit, Greater Manchester Neuroscience Centre, Salford Royal NHS Foundation Trust, Salford, UK
[b] Division of Neuroscience and Experimental Psychology, Faculty of Biology, Medicine and Health, University of Manchester, Manchester, UK

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ABSTRACT

Semantic dementia, a circumscribed disorder of semantic knowledge, provides a unique model for understanding the neural basis for semantic representation. The study addressed areas of contention: the relative roles of the left and right temporal lobe, the contribution of anterior versus posterior temporal cortex and the status of the anterior temporal lobes as amodal hub. Naming and word comprehension was examined in 41 semantic dementia patients, 31 with left-predominant and 10 right-predominant atrophy. In keeping with expectation, naming and comprehension were significantly poorer in left-predominant patients. Structural magnetic resonance image analysis, using a visual rating scale, showed strong inverse correlations between naming scores and severity of both left anterior and posterior temporal lobe atrophy. By contrast, comprehension performance was more strongly correlated with left posterior temporal atrophy. Analysis of naming errors revealed a correlation between anterior temporal atrophy and associative/functional descriptive responses, implying availability of semantic information. By contrast, 'don't know' responses, indicative of loss of semantic knowledge, were linked to left posterior temporal lobe atrophy. Semantic errors, the hallmark of semantic dementia, were linked to right hemisphere atrophy, especially the right posterior temporal lobe. Matched visual-verbal tasks (famous face and name identification, Pyramids and Palm trees pictures and words, animal knowledge from 3-D models and animal names) administered to nine patients elicited variable correspondence between performance on nonverbal and verbal versions of the task. Marked performance dissociations were demonstrated in some patients: poorer understanding of names/words in left-predominant patients and of faces/pictures/models in right-predominant cases. The findings are compatible with the notion of the anterior temporal lobes as areas of convergence, but are less easily accommodated

* *Corresponding author*. Cerebral Function Unit, Greater Manchester Neuroscience Centre, Salford Royal NHS Foundation Trust, Salford M8 8HD, UK.
E-mail address: julie.snowden@manchester.ac.uk (J.S. Snowden).

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within the framework of amodal conceptual representation. The data, which reconcile some apparent contradictions in the literature, are discussed in the light of the nature and distribution of degenerative change in semantic dementia.

1. Introduction

Semantic dementia is a disabling neurodegenerative disorder characterised by profound and widespread loss of conceptual knowledge (Snowden, Goulding, & Neary, 1989; Hodges, Patterson, Oxbury, & Funnell, 1992). It is associated with bilateral, albeit often asymmetric, atrophy of the anterior temporal lobes, with particular involvement of inferior and middle temporal gyri (Mummery et al., 2000; Chan et al., 2001; Rohrer et al., 2008). The disorder is underpinned by a unique frontotemporal lobar degeneration pathology, in which the abnormal protein is TDP-43 and the salient histological changes are of dystrophic neurites (Josephs et al., 2011; Snowden et al., 2011).

The cardinal presenting clinical feature is typically a difficulty in naming and in understanding words. In conversation, patients substitute generic terms for precise substantives (Hoffman, Meteyard, & Patterson, 2014) and they may use words over-inclusively. A hallmark of the disorder is the presence of semantic errors (e.g., 'banana' for apple; 'dog' for sheep), which is consistent with the gradual erosion of the capacity for discrimination between related concepts. With progression of disease, naming errors become decreasingly related to the target response (Hodges, Graham, & Patterson, 1995). The semantic disorder is not limited to language and progressively encompasses knowledge in all sensory domains. It affects the ability to recognise the meaning of objects (Snowden, Griffiths, & Neary, 1994; Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000), faces (Snowden, Thompson, & Neary, 2004; Josephs et al., 2008; Luzzi et al., 2017), voices (Luzzi et al., 2017), non-verbal environmental sounds (Bozeat et al., 2000; Goll et al., 2010), smells (Luzzi et al., 2007), tastes (Piwnica-Worms, Omar, Hailstone, & Warren, 2010; Omar, Mahoney, Buckley, & Warren, 2013) and tactile stimuli. By contrast, non-semantic cognitive skills remain well preserved. Patients are able to perceive normally stimuli that they cannot recognise, evidenced by their preserved performance on perceptual discrimination and copying tasks. The findings in semantic dementia exemplify the central distinction between semantic and pre-semantic levels of object processing, eloquently described by Humphreys and colleagues (Humphreys & Forde, 2001; Humphreys & Riddoch, 2006).

The striking, yet circumscribed, semantic loss in semantic dementia raises a number of theoretical questions. Perhaps the most central concerns the neural basis of semantic memory and, in particular, the role of the anterior temporal lobes. There is now widespread acceptance that semantic memory involves distributed neural networks. A prominent, influential view is that object concepts are grounded in action and perception (Martin, 2007; Barsalou, 2008; Kiefer & Pulvermüller, 2012; Meteyard, Rodriguez Cuadrado, Bahrami, & Vigliocco, 2012; Pulvermüller, 2013) as well as in emotion systems (Martin, 2016). By this view, object concepts are not explicitly represented but emerge from weighted activity within property-based brain regions. Hence, object concepts belonging to distinct categories such as animals and tools are represented in overlapping, but partially distinct, sensory- and motor property-based neural networks.

Nevertheless, the semantic loss in semantic dementia exceeds, both in terms of severity and range, that which is found in any other neurological condition. It points compellingly to a pivotal role of the anterior temporal lobes in semantic memory and led to the proposal of an anterior temporal lobe conceptual hub, which binds information from modality-specific systems and stores it in amodal format (Patterson, Nestor, & Rogers, 2007). Proponents of the semantic hub did not dispute the notion of a distributed semantic network, but rather argued that an additional amodal conceptual hub is necessary to serve as a convergence zone to support the interactive activation of representations in all modalities, for all semantic categories.

There are data that appear at odds with the notion of the anterior temporal lobes as an amodal semantic hub. Focal damage to the anterior temporal lobes has been reported to elicit few, if any, signs of semantic impairment (Bi et al., 2011; Busigny, de Boissezon, Puel, Nespoulous, & Barbeau, 2015). Many authors have associated the left anterior temporal region with problems in lexical retrieval (Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Mesulam et al., 2013; Miozzo & Hamberger, 2015), particularly for Proper nouns or other unique entities (Grabowski et al., 2001; Tranel, 2006, 2009; Busigny et al., 2015), rather than to frank semantic loss. Even when semantic impairments have been identified, for example following temporal lobe resection or vascular insults (Lambon Ralph, Cipolotti, Manes, & Patterson, 2010; Lambon Ralph, Ehsan, Baker, & Rogers, 2012) such deficits are relatively subtle and typically elicited only for low frequency stimuli. Activation studies too have typically shown little evidence of anterior temporal activation on semantic tasks, with many functional imaging studies reporting posterior rather than anterior temporal activation (Martin & Chao, 2001; Thompson-Schill, 2003). Some authors have argued that the lack of anterior temporal activation may be due to technical limitations and have demonstrated significant activation using transcranial magnetic stimulation

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