CORTEX 47 (2011) 575–587

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Research report

The role of the left anterior temporal lobe in language processing revisited: Evidence from an individual with ATL resection

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ARTICLE INFO

Article history:
Received 6 November 2008
Reviewed 17 March 2009
Revised 25 June 2009
Accepted 30 November 2009
Action editor Myrna Schwartz
Published online 22 December 2009

Keywords:
Anterior temporal lobe
Resection
Conceptual representation
Naming
Category specific

ABSTRACT

Various hypotheses about the role of the anterior temporal lobe (ATL) in language processing have been proposed. One hypothesis is that it binds the semantic/conceptual properties of words, functioning as a hub for linking modality-specific conceptual properties of objects. This hypothesis predicts that damage to ATL would give rise to impaired conceptual knowledge of all categories. A related school of hypotheses assumes that the left ATL is critical for lexical retrieval, with different sub-regions potentially important for different categories of items. We examined these hypotheses by studying a case of surgical resection of left ATL due to a low-grade glioma (LGG). Thorough language assessments performed four months after the operation revealed the following profile: the patient showed intact conceptual knowledge for all categories of items tested using both accuracy and response latency measures; he suffered from name retrieval deficits for proper names (people and place names) and artifacts (including tools), but showed no name retrieval difficulties for animate things. This pattern of results challenges both target hypotheses about the role of ATL in language processing tested here.

1. Introduction

The neuroanatomical basis for language processing has been studied using a wide range of paradigms, including lesion–function mappings in brain-damaged patients and functional brain–imaging studies on normal subjects and patients. While it is a current consensus that language processing involves a large network of anatomical regions mostly in the left hemisphere, including, but not restricted to the classical Broca's and Wernicke's areas (e.g., Damasio et al., 2004; Foundas, 2001; Spitsyna et al., 2006), specific hypotheses about brain-function relationships differ greatly. One example, which is the target issue of this article, is the role of the anterior temporal lobe (ATL) in language processing.

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doi:10.1016/j.cortex.2009.12.002

Here we consider two influential hypotheses about the role of ATL in language processing that were mainly motivated by neuropsychological evidence. One view is that ATL is the binding site of the semantic/conceptual[1] properties of words and objects (e.g., Patterson et al., 2007; Rogers et al., 2004; Rogers et al., 2006), and damage to this area will result in the loss of conceptual knowledge. Another hypothesis is that ATL in the dominant hemisphere is crucially involved in lexical retrieval (e.g., Damasio et al., 1996, 2004; Drane et al., 2008; Grabowski et al., 2001; Tranel, 2006, 2009). Below we briefly present these contrasting theories and relevant empirical findings.

The conceptual hub hypothesis was motivated by studies of a neurodegenerative disease – semantic dementia (SD) (see Patterson et al., 2007 for a review; Davies et al., 2005; Warrington, 1975). Patients suffering from SD usually show asymmetric, focal atrophy of the antero-lateral temporal lobe and a progressive loss of semantic knowledge about words and objects, as revealed by poor performance on neuropsychological tasks that require access to conceptual knowledge (e.g., word–picture matching, picture–drawing from memory, picture naming or object sound naming). These patients tend to retain knowledge of the common and typical features of objects but lose knowledge about more fine-grained features of those objects. For instance, patients typically draw similar images for all animals, i.e., having a head, two ears and four legs, omitting distinctive features such as the hump for camels. Some anatomy–function correlation studies have further suggested that the extent of atrophy in anterior temporal regions correlates with semantic impairment severity in SD patients (e.g., Mummery et al., 1999; Mummery et al., 2000; but see Martin, 2007 for alternative interpretations) and with meaningful cross-modal feature integration abilities (Taylor et al., 2009). These profiles were the strong motivation for Patterson et al. (2007) to propose that 1) there are amodal, abstract conceptual hubs that bind modality-specific properties which are grounded in the sensory–motor system (see also Caramazza and Mahon, 2006; Mahon and Caramazza, 2009) and 2) such amodal, abstract, item-specific conceptual ''hubs'' reside in bilateral ATL. We will refer to this theory as the ATL-conceptual hub theory. According to this theory, pathological changes of bilateral ATL will disrupt conceptual knowledge, affecting all kinds/modalities of semantic features of a concept. Evidence in accord with this theory has also been reported from other neurological groups including herpes simplex virus encephalitis (HSVE) and Alzheimer's disease and from neuroimaging studies (e.g., Binder et al., 2009; Lambon Ralph et al., 2007; Noppeney et al., 2007; see Patterson et al., 2007 for a review). Two recent studies (Lambon Ralph et al., 2009; Pobric et al., 2007) using repetitive transcranial magnetic stimulation (rTMS) over the temporal pole region in either left ATL or right ATL alone showed that temporary disruption of neural processes in these unilateral ATL region produced a selective slowing on tasks that involve semantic processing (e.g., word synonymy judgment) but not for non-semantic tasks (digit judgment). This result demonstrates that unilateral disruption alone is sufficient to induce semantic impairment. It is at least strong enough to affect response latencies, if not accuracies.

The other hypothesis of ATL's function in language processing is that it is involved in the intermediate stage between conceptual knowledge and word forms (e.g., phonological patterns for naming), Damasio et al., 1996, 2004; Rudrauf et al., 2008; Damasio et al. (1996) studied the relationship between lesion site in a group of 127 patients with brain damage (106 with stroke, others with HSVE or temporal lobectomy) and their performance on picture naming tasks. They analyzed the naming responses to only those items the patients could identify and, presumably, access the corresponding conceptual knowledge. The naming performance on these items was therefore hypothesized to reflect the ''lexical retrieval'', i.e., the intermediate stage between conceptual representation and words' phonological forms. One significant finding was that while patients showed a variety of categorical effects in their naming performance, such as disproportionate deficit for people, animals, or tools, there was no single case in their sample who showed deficits for both people and tools, leaving animals intact, and this pattern was not due to chance (Fisher exact probability test, $p = .0001$). The authors proposed that the left temporal pole, the left inferior temporal (IT) lobe, and the posterolateral inferior temporal lobe are important in name retrieval for people, animals, and tools, respectively. Because the temporal pole and the posterior IT regions are distant and do not overlap cortically or subcortically, it is virtually impossible for a single lesion to affect the retrieval of both people and tool names while leaving the animal items unaffected. Converging evidence for such a distribution of the three conceptual categories was provided by a positron emission tomography (PET) activation experiment where normal subjects named pictures of these categories of objects. The authors proposed that the existence of such category-specific intermediate regions for word retrieval is driven by the distribution of conceptual knowledge of the different categories. Subsequent studies (Damasio et al., 2004; Rudrauf et al., 2008) by the same group, using improved methods for the analysis of behavior–lesion mapping data, have come to similar conclusions in terms of the role of ATL in naming. Nonetheless, the categorical distinctions were less crisp in the most recent study (Rudrauf et al., 2008): left anterior inferior temporal region lesions were found to be associated with naming deficits for all categories and left lateral posterior IT lesions with naming deficits for both animals and tools. Recognition deficits of faces were associated with right temporal lobe lesions, and deficits of tool recognition were associated with left posterior lateral IT lesions. Thus, unlike the original proposal by this group (Damasio et al., 1996) their most recent proposal would predict a naming impairment for all categories following left ATL lesion. Either way, the results by this group of researchers suggest that left ATL is involved in aspects of language processing that are beyond the conceptual level, involving an intermediate stage between conceptual knowledge and word forms.

Patients who underwent left ATL lobectomy as treatment for temporal lobe epilepsy (TLE) usually exhibit good semantic knowledge but selective difficulty for naming people, and other proper name entities, (e.g., Fukatsu et al., 1999;

[1] These two terms are interchangeable in the paper without any implied distinctions.