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Segregation of anterior temporal regions critical for retrieving names of unique and non-unique entities reflects underlying long-range connectivity

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ABSTRACT

Lesion–deficit studies support the hypothesis that the left anterior temporal lobe (ATL) plays a critical role in retrieving names of concrete entities. They further suggest that different regions of the left ATL process different conceptual categories. Here we test the specificity of these relationships and whether the anatomical segregation is related to the underlying organization of white matter connections. We reanalyzed data from a previous lesion study of naming and recognition across five categories of concrete entities. In voxelwise logistic regressions of lesion–deficit associations, we formally incorporated measures of disconnection of long-range association fiber tracts (FTs) and covaried for recognition and non-category-specific naming deficits. We also performed fiber tractwise analyses to assess whether damage to specific FTs was preferentially associated with category-selective naming deficits. Damage to the basolateral ATL was associated with naming deficits for both unique (famous faces) and non-unique entities, whereas the damage to the temporal pole was associated with naming deficits for unique entities only. This segregation pattern remained after accounting for comorbid recognition deficits or naming deficits in other categories. The tractwise analyses showed that damage to the uncinate fasciculus (UNC) was associated with naming impairments for unique entities, while damage to the inferior longitudinal fasciculus (ILF) was associated with naming impairments for non-unique entities. Covarying for FT transection in voxelwise analyses rendered the cortical association for unique entities more focal. These results are consistent with the partial segregation of brain system support for name retrieval of unique and

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non-unique entities at both the level of cortical components and underlying white matter fiber bundles. Our study reconciles theoretic accounts of the functional organization of the left ATL by revealing both category-related processing and semantic hub sectors.

1. Introduction

A growing body of literature supports the hypothesis that the anterior temporal lobes (ATLs) play a critical role in the retrieval of semantic knowledge. Accessing semantic knowledge entails activating meaning-based mental representations of entities (e.g., 'rabbit') that are abstracted from specific autobiographical experiences (Tulving, 1972).

Evidence that the ATLs are critical for accessing semantic knowledge has come primarily from two lines of inquiry: 1) lesion–deficit association studies of patients with stable circumscribed brain damage (Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996, Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Drane et al. 2008, 2013) and 2) analysis and computational modeling of cognitive impairments associated with semantic dementia (SD) (Hodges, Patterson, Oxbury, & Funnell, 1992; Lambon Ralph, McClelland, Patterson, Galton, & Hodges, 2001; Patterson, Nestor, & Rogers, 2007; Rogers et al., 2004, 2006). While both lines of research document a systematic relationship between ATL damage and semantic retrieval impairments, they have reached different conclusions regarding the functional organization of the ATLs with respect to semantic processing. Lesion studies have supported the hypothesis that partially segregated systems within the ATLs support access to different types of semantic knowledge, with the left ATL specifically supporting access to verbal stores. By contrast, computational models designed to explain SD symptoms have supported the hypothesis that the ATLs function as an integrated semantic system. Central to these differing interpretations are two longstanding topics of debate in neuropsychology: the organization of the brain in integrated versus modality-specific, and/or category-related semantic knowledge store(s); and the interfacing of language with conceptual knowledge.

Lesion–deficit reports have emphasized that semantic deficits can be selective in nature, and that the selectivity is related to the topography of brain damage within and beyond the ATLs. In their original and subsequent studies, Damasio and colleagues investigated the neural correlates of selective deficits by separately operationalizing and assessing recognition and naming performance for several categories of concrete entities in a large group of lesion participants (Damasio et al., 1996, 2004; Tranel, Damasio, & Damasio, 1997). The results revealed a systematic relationship between the anatomic location of brain damage and the presence of impairments pertaining to specific conceptual categories of knowledge [e.g., unique ('Judy Garland') *vs* non-unique ('rabbit')]. Moreover, the pattern of findings supported the hypothesis that the neural substrates of name retrieval are distinct from those of concept retrieval (those that are sufficient for recognition but not naming), and that there is partial functional segregation of different sectors of the left ATL in supporting the retrieval of names from different semantic categories (Damasio et al., 1996, 2004). These results also highlighted the partial dissociation of the left temporal pole (LTP) and left inferotemporal cortex in the retrieval of names of unique entities (foremost famous persons) and non-unique entities, respectively, as well as the roles of the right temporal pole and posterior association regions in the recognition of unique versus non-unique entities (Damasio et al., 1996, 2004; Tranel et al., 1997; Tranel, Feinstein, & Manzel, 2008).

Damasio (1989) proposed that an architecture based on convergent (and reciprocally divergent) structural connectivity could explain the observed anatomical dissociations of semantic retrieval deficits in the brain (Damasio et al., 1996, 2004). According to this framework, conceptual knowledge is grounded in the binding pattern of multimodal "images" that are represented in early sensory and motor cortices. These cortices project onto higher-order association regions functioning as convergence–divergence systems that implement the binding pattern and provide feedback modulating the activity of sensory and motor cortices (Damasio, 1989; Mesulam, 2001). This arrangement, which is in part hierarchical, and involves bidirectional information flow, provides a functional architecture to support semantic knowledge as follows. 1) Cortical areas that process information about sensorimotor, interoceptive and/or emotional attributes support images that are the phenomenological primitives for the development of conceptual knowledge. 2) Sensorimotor neural patterns encoded in these areas successively converge on higher-order regions that integrate and abstract information as the basis for semantic representations of entities. 3) These latent representations may be retrieved through reactivation of bound patterns in early sensorimotor regions using the same hierarchy of convergence–divergence regions. 4) Category-related functional segregation effects emerge due to differences in the sensorimotor modalities and contingencies associated with different conceptual representations of entities (Farah & McClelland, 1991; Warrington & McCarthy, 1987; Warrington & Shallice, 1984). These requirements dictate the cortical location of the corresponding convergence–divergence regions. 5) Lexical retrieval is supported by regions that mediate the link between conceptual and word-form knowledge. As such, category-related anatomic effects propagate to convergence–divergence regions supporting retrieval of entity names, which are organized anatomically to link the convergence–divergence regions supporting their recognition and left perisylvian convergence–divergence regions supporting access to phonology and production.