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Research report

Distinct contributions of the fornix and inferior longitudinal fasciculus to episodic and semantic autobiographical memory

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ABSTRACT

Autobiographical memory (AM) is multifaceted, incorporating the vivid retrieval of contextual detail (episodic AM), together with semantic knowledge that infuses meaning and coherence into past events (semantic AM). While neuropsychological evidence highlights a role for the hippocampus and anterior temporal lobe (ATL) in episodic and semantic AM, respectively, it is unclear whether these constitute dissociable large-scale AM networks. We used high angular resolution diffusion-weighted imaging and constrained spherical deconvolution-based tractography to assess white matter microstructure in 27 healthy young adult participants who were asked to recall past experiences using word cues. Inter-individual variation in the microstructure of the fornix (the main hippocampal input/output pathway) related to the amount of episodic, but not semantic, detail in AMs – independent of memory age. Conversely, microstructure of the inferior longitudinal fasciculus, linking occipitotemporal regions with ATL, correlated with semantic, but not episodic, AMs. Further, these significant correlations remained when controlling for hippocampal and ATL grey matter volume, respectively. This striking correlational double dissociation supports the view that distinct, large-scale distributed brain circuits underpin context and concepts in AM.

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1. Introduction

Reliving our personal history, or autobiographical memory (AM), provides an important form of self-knowledge that is necessary for directing present and future behaviour, forging social bonds, and promoting continuity of the self over time (Bluck, Alea, Habermas, & Rubin, 2005). AM is not a single psychological construct but rather a multifaceted cognitive process involving both episodic and semantic details (Moscovitch et al., 2005; Tulving, 2002). Episodic AM involves remembering past events in a specific spatial and temporal context, and is typically characterised by the vivid retrieval of perceptual and emotional details. Alternatively, semantic AM contains general and self-related knowledge that is independent of the specific spatiotemporal encoding context and is considered to occur in the absence of 'mental time travel' (Levine, 2004; Tulving, 2002). Though presumed distinct (Moscovitch et al., 2005), episodic and semantic AM systems are highly interactive and can influence each other (Greenberg & Verfaellie, 2010; Irish & Piguet, 2013). Thus, it has been a major challenge to identify whether these AM components arise from dissociable neural systems.

Functional neuroimaging studies suggest that episodic AM retrieval recruits medial temporal lobe (MTL) but also midline structures, including posteromedial and medial prefrontal cortices (Bonnici et al., 2012; Levine et al., 2004; Martinelli, Sperduti, & Piolino, 2013). For example, activity in the hippocampus (HC) has been shown to increase parametrically with the episodic 'quality' of AMs (e.g., contextual specificity, emotional vividness), underlining a potential key role of this region in re-experiencing past events (Addis, Moscovitch, Crawley, & McAndrews, 2004; Daselaar et al., 2008; Moscovitch et al., 2005). Semantic AM, on the other hand, has been associated with increased activation along the ventrolateral temporal cortex, including anterior temporal lobe (ATL) and occipitotemporal fusiform gyrus (Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004; Levine, 2004; Martinelli et al., 2013).

To date, neuropsychological studies provide the most compelling evidence for a potential dissociation between episodic/semantic AM. For instance, amnesic patients with MTL damage recall fewer personal episodic details alongside relatively preserved memory for semantic information (Klein & Gangi, 2010; Steinvorth, Levine, & Corkin, 2005). Further, episodic AM impairment has been shown to be related to the degree of MTL damage in both amnesia (Rosenbaum et al., 2008) and Alzheimer's disease (AD) (Gilboa et al., 2005; Irish et al., 2014). Gilboa et al. (2005) also found that semantic AM was strongly associated with grey and white matter atrophy in ATL and occipital lobe (Gilboa et al., 2005). In contrast, studies of semantic dementia (SD) – a disorder characterised primarily by bilateral degeneration of the ATL (Lambon Ralph, Jefferies, Patterson, & Rogers, 2017) – have found impaired memory for semantic details in AM but preserved memory for specific contextual details (Ivanoiu, Cooper, Shanks, & Venneri, 2006; Piolino, Belliard, Desgranges, Perron, & Eustache, 2003; Westmacott, Leach, Freedman, & Moscovitch, 2001). SD patients can also exhibit better memory for recent events but impaired retrieval of remote AMs (Graham & Hodges, 1997; Irish et al., 2011).

Overall, these studies suggest that the MTL, and in particular the HC, may be critical for the retrieval of episodic, but not semantic information, during real world memory retrieval (but see Klooster & Duff, 2015; Verfaellie, Bousquet, & Keane, 2014). Alternatively, retrieval of semantic details in AM seems dependent on structures along ventrolateral temporal cortex, in particular those regions affected in SD, including ATL.

Despite the evidence cited above, the notion that episodic/semantic AM are underpinned by distinguishable, dissociable neural systems remains controversial (Irish & Piguet, 2013). To date, there has been no demonstration, within the same study, that focal damage to the HC and ATL selectively impacts episodic and semantic AM, respectively. Progressive atrophy in lesion models, such as the effects of HC atrophy in later stages of SD (Maguire, Kumaran, Hassabis, & Kopelman, 2010; Matuszewski et al., 2009), and of progressive ATL atrophy in AD (Domoto-Reilly, Sapolsky, Brickhouse, & Dickerson, 2012), makes inferences about specific structures, and their association with different AM components, challenging. Critically, despite recognition that AM arises from large-scale network-level communication between brain areas (Andrews-Hanna, Saxe, & Yarkoni, 2014; Levine, 2004), few studies have directly explored how structural connectivity within broader, distributed brain circuits underpins differences in episodic and semantic AM. While lesion studies suggest the involvement of specific brain structures, it is unclear to what extent this reflects the intrinsic processing of those regions, or wider network-level disruption (Collins et al., 2017; Shamy et al., 2010), particularly given that both episodic and semantic AM appear to engage larger brain networks in healthy controls (Levine et al., 2004; Martinelli et al., 2013).

A novel, network-level approach to testing this potential dissociation is to use diffusion magnetic resonance imaging (dMRI) to examine how inter-individual variation in the microstructure of white matter fibre bundles to and from these putative AM regions predict individual variation in episodic and semantic AM, presumably by influencing the transfer of distinct types of AM content within distributed neural networks (Fields, 2015; Mesulam, 1990). We tested, therefore, whether the tissue microstructural properties of the fornix would relate to the amount of episodic, but not semantic, detail within AMs. The fornix is the major input/output pathway of the HC (see above), and contains axonal projections to the medial prefrontal cortex, mammillary bodies and the anterior thalamic nuclei (Amaral & Lavenex, 2006). Similar to HC lesions, fornix damage in humans causes deficits in episodic recollection (Calabrese, Markowitsch, Harders, Scholz, & Gehlen, 1995; Vann et al., 2009), and diffusion MRI studies show that fornix microstructure predicts episodic memory performance (Metzler-Baddeley, Jones, Belaroussi, Aggleton, & O'Sullivan, 2011). Despite these findings, it is unknown whether fornical microstructure is associated with the ability to recall episodic information within AM. Such a role is feasible given the contribution of other interconnected regions of the so-called "extended HC network" (Gaffan, 1994) to episodic AM, including medial prefrontal cortex (Bonnici et al., 2012).

A second question is whether the amount of semantic information within AMs is less dependent upon an extended HC