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Names and their meanings: A dual-process account of proper-name encoding and retrieval

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Highlights

- Fronto-temporal and temporo-occipito-parietal regions support proper-name retrieval
- Unitized and socio-emotional encoding enables subsequent retrieval of proper names
- Non-unitized item-context encoding separately enables proper-name retrieval
- These dual mnemonic processes explain divergent network activations at retrieval
- The dual-process account elucidates diverging meanings that proper names pick out

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Abstract

The ability to pick out a unique entity with a proper name is an important component of human language. It has been a primary focus of research in the philosophy of language since the nineteenth century. Brain-based evidence has shed new light on this capacity, and an extensive literature indicates the involvement of distinct fronto-temporal and temporo-occipito-parietal association cortices in proper-name retrieval. However, comparatively few efforts have sought to explain how memory encoding processes lead to the later recruitment of these distinct regions at retrieval. Here, we provide a unified account of proper-name encoding and retrieval, reviewing evidence that socio-emotional and unitized encoding subserve the retrieval of proper names via anterior-temporal–prefrontal activations. Meanwhile, non-unitized item-item and item-context encoding support subsequent retrieval, largely dependent on the temporo-occipito-parietal cortex. We contend that this well-established divergence in encoding systems can explain how proper names are later retrieved from distinct neural structures. Furthermore, we explore how evidence reviewed here can inform a century-and-a-half-old debate about proper names and the meanings they pick out.

Key words: proper names; memory encoding; lexical retrieval; uncinate fasciculus; dual mnemonic process; familiarity memory; associative memory; item-context memory; socio-emotional memory; unitization; philosophy of language; naming and reference

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1. Introduction: Dual processes in proper-name encoding and retrieval

Proper names are lexical items that can pick out unique entities that are either perceived in the world around us (as in *Venus,* also known both as *the Morning Star* and *the Evening Star)* or are conjured from our internal conceptual structures (as in *Clark Kent* and his alias *Superman*). Proper names have been subject to debates in the philosophy-of-language literature since the nineteenth century, largely stemming from disagreement as to whether they directly denote entities in the external world, or, instead, pick out more complex meanings associated with the entity being named (Mill, 1858; Frege, 1948; Russell, 1911; Kripke, 1972).

More often than not, the people or entities named with a proper name are unambiguously unique and are familiar to speakers who use the name in common. Despite this shared usage, distinct speakers (or even a single speaker) may hold contradictory beliefs about the entity being named. For example, Venus can be called the Morning Star when it appears in the east but the Evening Star when appearing in the west. If one is unaware that the same planet is appearing in different contexts, one can affirm that Venus is the Morning Star while denying that it is the Evening Star (Frege, 1948). In the philosophy of language, debates about the semantics of such contradictory usages of proper names sought to elucidate questions about the nature of meaning, belief, and the interactions of language, mind, and world around us.

From the point of view of cognitive neuroscience, research on the ability to express meaning largely involves studying processes of memory encoding and lexical retrieval. However, despite extensive literature on the networks involved in face-name encoding and proper-name retrieval, few proposals have sought to integrate findings from these studies to inform the nature of proper names and the meanings they pick out. Here, we review neuroanatomical, lesion, and functional imaging evidence for the networks supporting the encoding of knowledge about unique entities and the later accessing of that knowledge during the retrieval of lexical items.

We propose that certain white-matter tracts, most saliently the left uncinate fasciculus (UF), but also the inferior longitudinal fasciculus (ILF), and the inferior fronto-occipital fasciculus (IFOF), and grey-

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matter structures that they connect — left orbital and medial prefrontal cortices (OMPFC), temporal pole, medial temporal lobe (MTL), and posterior temporo-occipito-parietal region, as well as the thalamus — are integrated into an encoding and retrieval network for proper names. We argue that the interactions of these regions with contralateral homologue structures during lexical retrieval and in broader aspects of cognition provide key insights into the kinds of meanings that proper names pick out.

Bilateral UF connections to the anterior MTL enable the encoding of information about unique entities that is later accessed via the orbitofrontal cortex and temporal pole during proper-name retrieval (Alm, Rolheiser, & Olson, 2016; H. Damasio, Grabowski, Tranel, Hichwa, & A. R. Damasio, 1996; Kirwan & Stark, 2004; Papagno et al., 2011; Sperling et al., 2003; Zeineh, Engel, Thompson, & Bookheimer, 2003). Moreover, the UF's important role in social and emotional cognition (Craig et al., 2009; Kitis et al., 2012; Motzkin, Newman, Kiehl, & Koenigs, 2011; Olson, Plotzker, & Ezzyat, 2007; Von Der Heide, Skipper, Klobusicky, & Olson, 2013) is suggestive of the nature of information encoded in anterior regions that enables subsequent retrieval.

We review evidence indicating that this network supports the encoding of unitized memories that often enable subsequent familiarity judgements at retrieval, but which more readily support explicit recall when socio-emotional information is encoded as a feature of items (see Dolcos, LaBar, and Cabeza, 2004; Yonelinas, 2002; Yonelinas et al., 2010; Fenker et al., 2005; Rugg and Curran, 2007; (Murray & Kensinger, 2013; Yonelinas & Ritchey, 2015). We propose that unitization potentiated by socio-emotional arousal — enabling associative encoding of memories that are subsequently retrieved as a single integrated entity — supports the later recall of proper names via the UF-connected anterior temporal–prefrontal network.

Temporal regions lying immediately caudal to the UF-connected temporal pole, as well as posterior temporal regions, bordering the occipital and parietal lobes, have also regularly been evidenced to support both common noun and proper-name retrieval (H. Damasio et al., 1996; Gorno-Tempini et al., 1998; Grabowski et al., 2001; Mehta et al., 2016; Semenza, 2006, 2011; Semenza & Zettin, 1988). We propose that the hippocampus and parahippocampal cortex encode information later

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accessed at retrieval by a second network running along this rostro-caudal axis of the temporal lobe, with both encoding and retrieval being supported by the ILF and the IFOF's posterior temporal connections. This (para)hippocampal item-item and item-context encoding forms non-unitized mnemonic associations that are typically implicated in recollection-based retrieval, supported primarily by posterior temporal and parietal regions (Eichenbaum, Yonelinas, & Ranganath, 2007; Yonelinas, 2002; Yonelinas, Otten, Shaw, & Rugg, 2005; Diana, Yonelinas, & Ranganath, 2010). This memory system is posited to support the retrieval of both proper names and common nouns from a posterior projecting network connecting the temporo-occipito-parietal region.

Under this account, then, information enabling the retrieval of proper names is encoded via two distinct processes, one that forms unitized mnemonic units that tend to encode socio-emotional information, the other non-unitized item-item and item-context associative memories that tend to be less emotionally arousing. Both the anterior fronto-temporal and posterior temporo-occipito-parietal networks supporting these processes are integrated via shared connections with the anterior MTL and PFC (Amaral & Lavenex, 2007; Papinutto et al., 2016; Van Hoesen & Pandya, 1975; Van Hoesen, Pandya, & Butters, 1975; Thiebaut de Schotten, Dell'Acqua, Valabregue, & Catani, 2012).

In section 2, we explore in detail the networks involved in proper-name retrieval, as evidenced through semantic dementia, lesion, and functional imaging studies. Following this, in section 3 we review the literature on face-name encoding, before spelling out the dual-process model of proper-name encoding and retrieval defended here. In section 4, we explore the implications of the dual-process account for theories of proper naming, long-debated in the philosophy of language but rarely considered in terms of neuroscientific evidence. We also propose means by which our model can be experimentally tested.

2. Proper-name retrieval networks

Lexical retrieval is a complex and integrative process, depending on many brain regions and multiple cognitive resources. These include accessing perceptual and conceptual representations, engaging

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control mechanisms to select suitable lexical items among various competitors, linking from conceptual to lexico-semantic or semantically categorized conceptual representations at distinct 'convergence zones' and/or at a single 'semantic hub', and, finally, accessing phonological and motor output systems, with their own fine-grained functional subdivisions (A.R. Damasio, 1989; H. Damasio et al., 1996; Patterson, Nestor, and Rogers, 2007; Jefferies, Patterson, and Lambon Ralph, 2008; Friedmann, Biran, and Dotan, 2013; Lewis and Poeppel, 2014; Gainotti, 2017). As we are most concerned here with the meanings that names pick out, most of our discussion concerns the conceptual–semantic systems supporting lexical retrieval rather than phonological (or graphemic) output systems.

The separation and definition of the above cognitive domains remains controversial, including disagreement as to whether conceptual and semantic knowledge should be considered distinct from each other, whether this information is stored in modality-specific or in amodal format, and whether different conceptual and semantic categories are stored in separate modules in the brain (see e.g. A. R. Damasio, 1989; Barsalou et al., 2003; Rogers et al., 2004; Patterson, Nestor, and Rogers, 2007; Barsalou, 2008; Gainotti, 2017). Here below we review lesion evidence that predominantly leftward temporal lobe structures support the retrieval of lexical items including proper names, while damage to right temporal and bilateral orbital and medial prefrontal regions consistently leads to deficits in retrieving knowledge about individuals, rather than anomias. While this may suggest a qualitative left-right distinction between lexico-semantic and conceptual knowledge, it may also reflect effects on left-dominant language processing acting over conceptual representations that are otherwise qualitatively similar in both hemispheres (Gainotti, 2017). As such, we remain agnostic as to whether the anomias described here below are symptomatic of inherently semantic or conceptual deficits.

2.1 The temporal pole and proper names

Converging evidence from semantic dementia, lesion, and functional imaging studies leaves little doubt as to the importance of the left temporal pole in proper-name retrieval. The right temporal pole supports the recognition of unique individuals.

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Proper names are frequently the first lexical items lost in semantic variant primary progressive aphasia (svPPA or PPA-S) (Costanza Papagno & Capitani, 1998; Snowden, Thompson, & Neary, 2004). Left anterior temporal lobe (ATL) deterioration is a feature of svPPA, which has sometimes been equated with semantic dementia (SD) or the fluent variant of PPA (Mummery et al., 2000). Mesulam et al. (2009) distinguish between svPPA and SD, with deficits in the former being language-specific (loss of semantic knowledge), whereas, in the latter, impaired face and object recognition can accompany semantic deficits. SD is usually marked by bilateral deterioration of the ATL, with most severe damage occurring in the left temporal pole, where the atrophy is thought to originate (Papagno and Capitani, 1998; Mummery et al., 1999; Mummery et al., 2000; Gorno-Tempini et al., 2011; Collins et al., 2017).

Papagno and Capitani (1998) found that a svPPA patient with circumscribed atrophy in the left ATL had no deficits for retrieving common nouns, but significant deficits in retrieving proper names for famous people, places, and brands. Naming deficits for famous people were not accompanied by concomitant deficits in relaying knowledge about those people. As atrophy progressed throughout the left temporal lobe, common nouns began to be affected. Snowden, Thompson, and Neary (2004) found that the more significant the atrophy in the left ATL in SD, the greater the deficits in recognizing and identifying famous names. Atrophy in the right ATL correlated with deficits in face recognition and identification.

H. Damasio et al. (1996) found that left temporal pole lesions across numerous patients significantly correlated with deficits in naming famous people (without deficits in recognizing images of them), while no subjects with retained people naming had temporal pole lesions. Where patients had deficits in people naming only, lesions were limited to the most anterior portion of the left temporal pole. In the same study, Positron emission tomography (PET) scans of healthy subjects also showed activations in the left temporal pole for the retrieval of people's names. In another PET study, Grabowski et al. (2001) found left temporal pole activations to be the main effect of naming famous faces and landmarks versus processing unknown entities. The right temporal pole was most significantly activated for the recognition of famous faces.

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The evidence reviewed above suggests that the left-temporal pole is particularly important in retrieving lexico-semantic information relevant to unique entities, while its rightward homologue supports the retrieval of non-lexical conceptual and perceptual information about unique entities.

2.2 Beyond the temporal pole: A dispersed network for proper-name retrieval

Functional imaging studies have indicated that an extensive network beyond the temporal pole supports proper-name retrieval. The extent of these networks, which include subcortical and limbic structures, underscores the point that proper-name retrieval does not solely depend on language-dominant regions of the temporal cortices.

Structures implicated in proper-name retrieval include the left inferior frontal cortex, left medial prefrontal cortex, left retrosplenial region, left collateral sulcus, left central cortex, right posterior superior parietal lobe, left temporo-parietal junction, left posterior temporal/occipital region, left basal ganglia (including the left thalamus), the amygdala, and the right cerebellum (Gorno-Tempini et al., 1998; Grabowski et al., 2001; Semenza 2006, 2011). Based on a combined PET and lesion study, H. Damasio et al. (2004) proposed a predominantly leftward proper-name retrieval network that includes both temporal poles, the left anterior inferior temporal gyrus, left anterior superior temporal sulcus, left frontal operculum (pars orbitalis), left anterior medial prefrontal cortex, and left anterior cingulate gyrus. These authors suggest a rightward network for person-related concept retrieval that includes the temporal pole, anterior inferior temporal gyrus, anterior parahippocampal gyrus, lateral occipital lobe, and temporo-occipital junction.

There is much convergence among the above studies, although Gorno-Tempini et al. (1998), Grabowski et al. (2001), and Semenza (2006, 2011), unlike H. Damasio et al. (2004), all highlight the importance of left posterior temporal regions bordering the occipital and parietal lobes in proper-name retrieval. As with studies of SD patients, lesion-deficit correlations can help to pinpoint which parts of the proper-naming network are especially important for the retrieval of conceptual or lexico-semantic information that supports the recall of a name. Cases of near global proper-name anomia have occurred in patients with two very different neural pathologies: left parieto-occipital stroke and left fronto-

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temporal lesion (Semenza and Zettin, 1988; 1989), lending support to the idea that both anterior and posterior cortical regions are engaged in proper-name retrieval.

Anterior and mediodorsal thalamic damage can result in naming deficits similar to those associated with the temporal pole, including increased susceptibility to person over place-name loss (Lucchelli and De Renzi, 1992; H. Damasio et al., 1996; Miller, Caine, & Watson, 2003) and improved naming performance when given phonemic as opposed to semantic cues (Lucchelli & De Renzi, 1992; Semenza & Sgaramella, 1993; Cohen et al., 1994; Otsuka et al., 2005). We consider there to be strong evidence from lesion and functional imaging studies that left thalamic, inferior prefrontal-temporal pole, and temporo-occipito-parietal regions are most consistently implicated in proper-name retrieval. Further below, we present evidence for these regions' structural and functional integration via white-matter tracts.

2.3 Proper-name and common-noun retrieval deficits: convergent and divergent patterns

Although we are primarily concerned with proper-name retrieval deficits, it should be noted that, as atrophy extends posteriorly in the left temporal lobe of svPPA or SD patients, lexical retrieval deficits become more extensive, including both proper and object naming, and word association deficits. Grammatical competence and non-verbal object matching often remain normal (Mesulam et al. 2013). This raises the possibility that posteriorly connected networks for proper-name retrieval identified in studies reviewed above are engaged in broader lexical retrieval.

Nonetheless, evidence of extensive and selective proper-name anomias (as in Semenza and Zettin 1988; 1989) suggests that proper-name retrieval depends, at least in part, on a separate network from that of other lexical items. In healthy populations, proper names are generally more difficult to retrieve than common nouns, even in cases where these lexical items are matched in their phonological form (e.g. Baker/baker: McWeeny, Hay, & Ellis, 1987). Cases of selective proper-name anomias can extend to names of personally familiar people, including friends and family members, which should presumably be relatively easy items to retrieve, while sparing infrequently occurring common nouns (Semenza & Zettin, 1988; Miceli et al., 2000). Lexical retrieval deficits that pattern with or dissociate

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from proper-name loss can tell us much about shared and distinctive cognitive resources upon which proper-name retrieval depends. We explore these patterns here.

The loss of highly specific common nouns (as in *sparrow* rather than *bird*) can accompany that of proper names in SD patients with predominantly left ATL atrophy (Gorno-Tempini, Dronkers, et al., 2004). This observation has been corroborated by functional imaging data from healthy individuals, showing similar activations in the temporal pole for the retrieval of person names and specific common nouns (Rogers et al., 2006). This finding contrasts with H. Damasio et al. (1996), who had found that patients with lesions mainly in the inferior temporal lobe typically exhibited deficits in naming animals, while more posterior temporal lobe lesions, often encroaching on occipital and parietal regions, led to deficits in naming tools. Unlike in SD studies, these authors did not observe significant correlations between posterior temporal lesion and proper-name retrieval deficits.

These discrepancies may be explained by partially overlapping white-matter networks connecting posterior and anterior temporal regions subserving distinct lexical retrieval processes. Mehta et al. (2016) have shown that, within the left ATL, lesions limited to the temporal pole correlate with the loss of proper names, while anterior temporal lesions lying caudally to the polar region correlate with both proper-name and common-noun loss. These authors also show that such partial dissociations of lexical retrieval deficits are likely to emerge from distinct patterns of long-range-association-tract disconnection, with left UF disconnection from prefrontal areas correlating uniquely to proper-name loss and left ILF damage, disconnecting posterior temporal and occipital areas leading to both proper-name and common-noun loss.

These findings suggest that the retrieval of both proper names and common nouns engages shared cortical regions and white-matter tracts along the longitudinal axis of the left temporal lobe, whereas the most anterior portion of the left temporal pole, with its distinctive white-matter connections, is more specifically engaged in the retrieval of proper names. Below, we detail the white-matter tracts integrating thalamic, inferior prefrontal, temporal pole, and temporo-occipito-parietal regions often associated with these distinct retrieval deficits.

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2.4 White-matter connections integrating proper-name retrieval regions

Prefrontal and anterior temporal regions implicated in processing information about individuals and in proper-name retrieval are connected by the uncinate fasciculus (UF). These include the orbitofrontal cortex (OFC: BA 10, 11, and 47), (ventro)medial prefrontal cortex ([V]MPFC: BA 12, 25, and 32), temporal pole (BA 38), amygdala, anterior parahippocampal gyrus (divisible into the entorhinal [BA 28 and 34] and the perirhinal cortices [BA 35 and 36]), and perhaps the anterior inferior temporal gyrus (BA20) (Ebeling and von Cramon, 1992; Chabardès et al., 2002; Kier et al., 2004; Martino et al., 2011; Thiebaut de Schotten et al., 2012; Catani et al., 2013; Dick, Bernal, and Tremblay, 2014; Vassal et al., 2016). Atrophy in SD is thought to spread from the anterior temporal cortex to the VMPFC and the amygdala via progressive degeneration of the UF (Mummery et al., 2000; Agosta et al., 2009).

Papagno et al. (2011) found that glioma patients who had temporal-pole and medial-temporal portions of the UF removed, showed the clearest deficits in proper-name retrieval, followed by those who had the frontal portion resected. On the whole, patients for whom the UF was preserved retained proper-naming abilities. In a follow-up study, performance for proper naming remained pathological in patients with the UF resected, while any other deficits, including the retrieval of common nouns, had returned to normal. Nonetheless, even in cases of total or near total UF resection, proper-naming deficits are not total: On average, patients without the UF scored half as well as those with fully-retained connections (Papagno et al. 2014). This fact led the authors to argue, following Semenza (2006), that if there is anything like a module for proper names, it is not uniquely located in UF-connected regions. This is supported by the lesion and imaging evidence cited above, which points to thalamic and temporo-occipito-parietal involvement in proper-name retrieval.

Given these lesion-deficit associations, white-matter connections to the thalamus and posterior cortical regions must be integrated in any full account of proper-name retrieval networks. The ILF runs from the occipital lobe along the inferior temporal gyrus, connecting the inferior portion of the temporal pole (Kondo, Saleem, and Price, 2003; Papinutto et al., 2016). The temporal pole's dorsal portion connects to the auditory cortex via the middle longitudinal fasciculus (MLF) (Dick and Tremblay 2012;

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Dick, Bernal, and Tremblay 2014; Vassal et al., 2016). Yasuda, Beckmann, and Nakamura (2000) proposed that the inferior longitudinal fasciculus (ILF) integrates a semantic hub for proper names in the left posterior temporal / occipital region with a phonological hub in the temporal pole. However, this proposed network for proper names does not take UF contributions into account and would have a hard time explaining proper-name retrieval deficits associated with damage to prefrontal regions.

There is evidence that the ILF relays visual content from occipital to anterior temporal regions: The extent of degradation of bilateral ILF fibers in children with cerebral visual impairment has been shown to correlate with the extent of object recognition deficits (Ortibus et al., 2012). Right ILF degradation has been implicated in both face and object recognition deficits with retained semantic knowledge (Grossi et al., 2014), while left ILF dysfunction has been implicated in object naming deficits (Shinoura et al., 2010). However, brain stimulation tasks have failed to confirm ILF involvement in object naming, instead strongly suggesting a role for the IFOF, which connects occipital and posterior temporal regions to the OFC (Mandonnet et al., 2007; Duffau et al., 2005). Damage to the IFOF and UF have also been associated with loss of recognition of famous individuals from the presentation of voice stimuli (Papagno, Mattavelli, Casarotti, Bello, & Gainotti, 2018). Given the evidence for the ILF's involvement in object and face recognition, this tract is a strong candidate for relaying visual inputs about people and objects to the anterior temporal lobe. This may go some way to explaining left temporal-pole involvement in retrieving specific common nouns (Gorno-Tempini, Dronkers, et al., 2004; Rogers et al., 2006), with the ILF relaying detailed object information anteriorly, while more general (superordinate) object distinctions are processed in the posterior temporal / occipital region.

As for the thalamus, its mediodorsal, anteromedial, midline, and intralaminar nuclei connect to the orbital and medial prefrontal cortices via two separate loops (Price, 2007). The UF has strikingly similar limbic, orbital, and medial prefrontal connections to these loops, and there are direct reciprocal projections from the mediodorsal thalamus to the amygdala and the temporal pole via the inferior thalamic peduncle (Behrens et al., 2003). A plausible explanation as to why thalamic lesions should bring about proper-name anomias is that damage disrupts mechanisms for engaging cortical and subcortical

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regions “to bind semantic features/concepts to the corresponding lexical representation” (Crosson, 2013).

2.5 Summary of evidence for distinct proper-name retrieval networks

The lesion and functional-imaging evidence reviewed above suggests that distinct cortical regions at either end of the temporal lobe support proper-name retrieval: At the rostral extreme, the ATL bilaterally support the retrieval of information about highly specific entities, with the polar regions supporting the retrieval of information about unique entities. At the caudal end, the posterior temporo-occipito-parietal junction supports the retrieval of information about both superordinate (non-specific) and unique entities. The language-dominant left hemisphere is implicated in the retrieval of lexical items for both unique and non-unique entities, with the left temporal pole supporting the retrieval of proper names, the ATL, caudal to the polar region, supporting the retrieval of highly-specific common nouns, and the posterior temporo-occipito-parietal junction supporting the retrieval of both common nouns and proper names.

The distinct posterior and anterior temporal regions supporting proper-name retrieval are integrated by partially overlapping white-matter connections. The temporal pole is connected to the OMPFC by the uncinate fasciculus (UF). Damage to the left UF in either temporal or prefrontal lobes affects proper-name retrieval over and above any other discernible and lasting language deficits. The temporo-occipito-parietal junction is connected by the inferior fronto-occipital fasciculus (IFOF) to many of the same inferior PFC regions as the UF. The inferior longitudinal fasciculus (ILF) connects posterior temporal and occipital regions to the ATL, terminating caudally to the most anterior temporal-pole connections of the UF. Distinct studies have implicated both the ILF and IFOF in the recognition of both unique and non-unique entities, as well as in naming deficits.

These studies provide strong evidence that the neural substrates of proper-name retrieval partially overlap with those for the retrieval of common nouns, particularly in posterior regions of the temporal lobe connected by the IFOF and ILF. By contrast, when it comes to lexical retrieval, anterior

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connections by means of the UF-connected temporal pole appear to be exclusively involved in the retrieval of proper names.

These white-matter connections to regions implicated in distinct patterns of proper-name and common-noun retrieval deficits provide evidence for partially overlapping networks subserving partially overlapping processes. Any account of these processes should attempt to explain how and why such divergent patterns should come about, including an explanation of the encoding processes that give rise to the distinct cortical instantiations described above. In section 3 we review evidence that distinct encoding processes in the MTL can give rise to divergent cortical instantiations of long-term memory that support later retrieval.

3. Cortico-subcortical connections in dual memory encoding processes: A model for the emergence of divergent proper-name retrieval networks

In their studies of the early stages of SD, both Hodges and Graham (1998) and Papagno and Capitani (1998) note that patients with atrophy limited to left ATL scored similarly to controls in providing information about contemporary famous people but worse when it came to famous people from the past. The former study proposed that preserved structural integrity of, and connections to, the hippocampus in SD allow for the formation of new memories enabling proper name retrieval, despite the erosion of long-term memories. In a follow-up of their study, Papagno and Capitani (2001) found that extensive bilateral atrophy encompassing the parahippocampal gyrus correlated with extended naming deficits including contemporary famous people. As described above, the medial projection of the UF connects to the entorhinal and perirhinal cortices, which, in tracing experiments, have been shown to relay the principal afferent and efferent connections to and from the hippocampus, including major projections from the UF-connected temporal pole and orbitofrontal cortex (Amaral and Lavenex, 2007; Van Hoesen, Pandya, & Butters, 1975; Suzuki and Amaral, 1994; van Hoesen and Pandya, 1975).

The hippocampal formation has long been known to play an essential role in the encoding of new memories. The UF–anterior parahippocampal connections detailed above, and the association of

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MTL atrophy with the loss of recently encoded proper names, suggest that these structures may be crucial to the encoding of proper names. Elucidating MTL interactions during encoding with regions that later enable retrieval should give a fuller picture of how the brain processes proper names. Below, we review literature on MTL regions that support face-name encoding. Following this, we detail dual-process accounts of memory encoding, how these point to distinct unitized versus non-unitized memory systems, and how socio-emotional versus neutral encoding processes can help to explain how divergent networks come to subserve subsequent proper-name retrieval.

3.1 Functional interactions of the MTL and UF-connected regions in face-name encoding and retrieval

Temporal pole and prefrontal activations, as well as diffusion tensor imaging studies, suggest a dual role for the UF in both proper-name encoding and retrieval. Alm, Rolheiser, and Olson (2016) found that left and right fractional anisotropy and leftward diffusivity measures in the UF (but not in the ILF) significantly predicted subjects' accuracy and learning rate in a face-name association task. In another task, UF microstructural measures were shown *not* to predict subjects' ability to memorize faces that were not associated with a name or any other item. A similar study (Thomas, Avram, Pierpaoli, & Baker, 2015) also showed that UF microstructure correlates with the ability to learn face-place associations. The authors of this study viewed the correlation as evidence of the UF's involvement in rapid associative encoding and recall.

Sperling et al. (2003) and Chua et al. (2007) observed increased activity in the bilateral anterior hippocampal formation and left inferior prefrontal cortex during encoding of face-name associations that were subsequently remembered. The latter study also noted fusiform and entorhinal activations at encoding that correlated with subsequent associative memory, with activity in the perirhinal and fusiform cortices predicting subsequent memory for faces. A separate study has shown subsequent memory for face-name associations to be significantly associated with hippocampal activations during encoding, as well as a tendency (although non-significant) for perirhinal activations to occur more often

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for successful than non-successful encoding of these associations (Westerberg, Voss, Reber, & Paller, 2012).

Kirwan and Stark (2004) found that activations during successful encoding of face-name associations occurred in the left amygdala, right hippocampus, and right parahippocampal cortex, while activations in the right perirhinal cortex and parahippocampal cortex predicted subsequent memory regardless of whether single items or associations were remembered. The retrieval of face-name associations correlated with activations in the right entorhinal cortex, right hippocampal region, right parahippocampal cortex, and a subsumed region in the left perirhinal cortex–temporal pole.

Zeineh et al. (2003) found that face-name associative encoding occurred primarily in the dentate gyrus (DG), CA2, and CA3 of the hippocampus, target regions of the entorhinal cortex's perforant pathway. Meanwhile, the retrieval of names upon presentation of a face activated the posterior subiculum and a small area of the anterior parahippocampal gyrus, fitting with the fact that the main efferent hippocampal pathway runs between these two regions. As the task was repeated, and face-name associations became better learned, activations in the hippocampus decreased, while increasing most significantly in the left anterior prefrontal cortex, left posterior superior temporal gyrus, right lateral posterior fusiform gyrus, and left ventral occipital cortex. The strong increase in cortical activity occurred presumably as information became encoded in (and thus retrievable from) cortical areas.

These anterior-versus-posterior cortical activations at retrieval following successful face-name encoding mark a similar pattern to those of retrieval and lesion studies explored in section 2. Moreover, there is a consistent pattern of dual anterior and posterior MTL activations during face-name encoding. Studies of different mnemonic processes in the MTL can help to sketch out how this pattern emerges and whether it can motivate broad anterior-versus-posterior divergence in proper-name retrieval networks. A similar division has been proposed for a broad range of behaviors in the prominent model of Ranganath and Ritchey (2012), where the UF-connected memory system supports person-specific memory, object perception, assessment of an entity's significance or value, and subsequent familiarity judgements. Meanwhile a posterior system including cingulate and retrosplenial areas, but also

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thalamic, hippocampal, and temporo-occipito-parietal regions, supports the perceptual processing of scenes, language-based representations of interactions between entities, actions, and outcomes, reasoning about others' mental states (theory of mind), and episodic/recollection-based memory (Ranganath & Ritchey, 2012).

3.2 Divergent mnemonic processes in the emergence of dual proper-name retrieval networks

Lesion and functional imaging studies provide extensive evidence that distinct structures along the longitudinal axis of the MTL support dual memory encoding processes, giving rise to divergent networks at retrieval (Yonelinas et al., 2002; Yonelinas et al., 2004; Bowles et al., 2007; Eichenbaum et al., 2007; Henson, Rugg, Shallice, Josephs, & Dolan, 1999; Yonelinas et al., 2005, Vilberg & Rugg, 2008; Ranganath & Ritchey, 2012).

The predominant paradigm used to elucidate the neural basis of divergent memory systems compares the behavioral correlates of *familiarity* (reporting knowledge that an event or item had been presented earlier, without being able to recall any details about it) with those of *recollection* (recalling details about an earlier event or learning task). When scanning is carried out during encoding, multiple studies have found that the anterior parahippocampal gyrus (perirhinal and entorhinal cortices) supports the encoding of memories for single items and item-item associations that are subsequently recognized as familiar (see Eichenbaum et al., 2007 for review; also Haskins, Yonelinas, Quamme, & Ranganath, 2008). Meanwhile the hippocampus predominantly supports the encoding of single and associated items, allowing for subsequent recollection (Eichenbaum et al., 2007; Staresina & Davachi, 2006), and the (posterior) parahippocampal cortex is often activated at encoding when contexts in which items presented are subsequently remembered (Diana, Yonelinas, & Ranganath, 2007; Staresina, Duncan, & Davachi, 2011).

When scanning happens at retrieval, MTL activations correlating with familiarity and recollection parallel with those often identified at earlier encoding (anterior parahippocampal regions supporting familiarity, the hippocampus supporting recollection, and the parahippocampal cortex supporting both item and context memory: Diana et al., 2007; Eichenbaum et al., 2007). This broad anterior-versus-

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posterior divergence extends to cortical retrieval networks: Each of Henson, Rugg, Shallice, Josephs, & Dolan (1999), Yonelinas et al. (2005), Vilberg & Rugg (2008), and Ranganath & Ritchey (2012) identify predominant — although not absolute — anterior-versus-posterior divergence in retrieval networks that largely overlap with the anterior-versus-posterior networks identified in subsection 2.2 for proper-name retrieval. Moreover, thalamic regions, which when damaged have been associated with proper-name anomias (see also subsection 2.2), have been shown to engage the distinct MTL structures identified here for the encoding and retrieval of memories supporting both familiarity judgements and recollection (Aggleton & Brown, 1999; Ketz, Jensen, & O'Reilly, 2015).

That a dual anterior-versus-posterior pattern of MTL activations at encoding should parallel with anterior-versus posterior activations at retrieval is consistent with the view that distinct mnemonic processes can drive the divergence of networks for proper-name retrieval. However, in order to use a name, one always has to *recall* the name being used, so familiarity, as defined in many of the studies reviewed above, would be insufficient. This entails that proper-name retrieval, whether dependent on anterior or posterior networks, must depend on encoding processes that allow for recollection.

Although recollection and familiarity are defined in terms of dichotomous behavioral phenomena at retrieval, the underlying neural mechanisms need not be purely dichotomous. In keeping with this — and despite broad anterior-versus-posterior divergence in memory systems — inferior PFC regions prominently implicated in familiarity judgements have also been associated with recollection, while in the parietal lobe, the angular gyrus has been implicated in familiarity-based retrieval (Ranganath, 2010; Henson et al., 1999; Yonelinas et al., 2005). At encoding, each of the perirhinal cortex, hippocampus, and parahippocampal cortex, or distinct combinations of these regions, have been shown to support the formation of associations that can support subsequent recall (Staresina & Davachi, 2006; Staresina et al., 2011; Ranganath, 2010; Wixted & Squire, 2011). Crucially, however, there is evidence that these associations are distinct in nature, leading to divergence in networks, both of which can support recollection, but with a greater tendency for anterior regions to support familiarity.

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Here we review evidence that anterior MTL regions (most prominently the perirhinal cortex, but also the hippocampus) support the encoding of unitized memory (Staresina & Davachi, 2010; Borders, Aly, Parks, & Yonelinas, 2017). Unitization is prominently associated with subsequent familiarity judgements, but can also support subsequent recall (Graf & Schacter, 1989; Haskins et al., 2008; Ranganath, 2010; Diana, Van Den Boom, Yonelinas, & Ranganath, 2011; Parks & Yonelinas, 2015). Meanwhile, the parahippocampal cortex and the hippocampus support non-unitized item-context and item-item associative encoding, commonly associated with subsequent recall (Diana, Yonelinas, & Ranganath, 2010; Staresina, Duncan, & Davachi, 2011; Ranganath & Ritchey, 2012; Aminoff, Kveraga, & Bar, 2013).

Unitization is an associative process in which two or more separate items, or features of an item, are combined to form a single mnemonic unit. This is enabled by perceived structural continuity or coherence between items and features, or by conceiving separate items as connected due to their being presented concurrently (Graf & Schacter, 1989). Examples include instances where separate words (e.g. *steam* and *boat*) are combined to form a compound word with a new singular meaning (*steamboat*), when separable features and items (e.g. color and item) are encoded together (Haskins et al., 2008; Staresina & Davachi, 2006, 2010), and when item and source context (e.g. task performance demands) are unitized (Diana, Yonelinas, & Ranganath, 2008). Unitized memories can support both recollection and familiarity judgements, although effects are often found to be greater for familiarity, and the extent to which items are unitized have been shown to increase familiarity-based retrieval but not recollection (Parks & Yonelinas, 2015). Effects of unitization on both recollection and familiarity are greater when associations are made across domains for a range of different stimuli (e.g. face-hobby associations: Parks & Yonelinas, 2015).

The perirhinal cortex has been shown to be particularly implicated in the encoding of unitized memories. Apart from being activated for the encoding of item-feature associations (e.g. color-item unitization) and of stimuli from a single processing domain (word-word compounds), the perirhinal cortex has also been implicated in cross-domain (word-picture) and inter-item visual (picture-picture)

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encoding of associations that were later recognized as familiar, and which have been suggested to result from unitization processes (Haskins et al., 2008; Park & Rugg, 2011; Staresina & Davachi, 2006, 2010). Based on lesion studies, it has been suggested that inter-item unitized encoding is more prominently supported by the hippocampus and item-feature unitization by the perirhinal cortex, although there is evidence for the involvement of each of these regions in either unitization process (Borders et al., 2017). Visual integration of object fragments to form a unitized item has been shown to occur in the ventral visual stream prior to perirhinal encoding (Staresina & Davachi, 2010). These ventral activations occur in multiple regions connected by the medial branch of the ILF (Latini et al., 2017; Staresina & Davachi, 2010).

Despite the fact that stimuli used to detect unitized encoding can vary broadly across studies, the associative processes identified provide plausible means by which one may attach a name to a unique entity. For example, face-name and picture-word encoding tasks are comparable in that they both involve cross-domain (visual-lexical) associations. Ostensibly, both types of tasks also test memory for item-item associations, as is clear in instances where scenes are presented alongside unrelated words at encoding (Park & Rugg, 2011). Yet proper names, by nature of being fixed identifiers of unique entities, differ considerably from incidental picture-word associations often used in task situations: Because the link (once established) between a unique entity and its name is essentially invariable, the name may also feasibly be encoded as a unitized item-feature association. This seems especially likely when the concurrent association of a unique entity with its name is repeated, underscoring the invariable nature of the association and aiding subsequent unitized recall. A related idea — that names are “attached to the objects themselves” (i.e. that they bear an inextricable and direct link to the unique entities they pick out) — was famously spelled out by John Stuart Mill (1858), spurring much subsequent debate in the philosophy of language.

In the case of unique individuals, face-name item-feature unitization may be comparable to making face-voice associations, especially in cases where individuals introduce themselves by uttering their own name, a common occurrence in initial face-name association. In such instances, both voices

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and names share the property of being concurrently presented and coherent with the individuals they uniquely identify, as is typical of associations encoded in a unitized manner (Graf & Schacter, 1989). The UF has been proposed to support the integration of both voices and names with information for unique individuals, while the left temporal pole subserves the retrieval of names from voice stimuli (Von Der Heide et al., 2013; Waldron, Manzel, & Tranel, 2014). Hippocampal and perirhinal activations during the encoding of face-name associations (e.g. Kirwan & Stark, 2004; Chua et al., 2007; Westerberg et al., 2012) may result, respectively, from distinct item-item (word-image) and intra-item (item-feature) unitization mechanisms.

The converse pattern of hippocampal and posterior MTL (parahippocampal cortex) activations during face-name encoding (e.g. Kirwan & Stark, 2004) may be explained in terms of evidence that these regions support non-unitized item-context and item-item encoding (Diana et al., 2007; Eichenbaum et al., 2007). The associative nature of these encoding processes is perhaps less controversial than that of unitization, in that they often support explicit recollection of associated stimuli at retrieval (Diana et al., 2010; Ranganath, 2010; Ranganath & Ritchey, 2012). As discussed further above, hippocampal activations at encoding often predict subsequent item-item recollection, including face-name pairs, while the hippocampus and parahippocampal cortex have been implicated in subsequent contextual item-and-source memory.

There is strong evidence that item-and-source memory supported by interactions between the hippocampus and parahippocampal cortex is processed in a non-unitized manner (Diana et al., 2010). In support of this, subsequent associative memory for face stimuli presented at a delay following earlier presentation of place and person names correlated with activations of a left posterior parahippocampal region. On the other hand, subsequent associative memory for names presented concurrently with faces correlated with activations in the hippocampus bilaterally, including an anterior region that also encompassed the amygdala (Qin et al., 2007).

The posterior encoding of non-unitized item-context and item-item information may help to explain why posterior cortical regions often implicated the retrieval of proper names also support

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common-noun retrieval. The relationship between proper names, common nouns, and contextual associations is apparent if we consider that contextual or episodic details about a person or entity must be relayed with common nouns, as in 'Venus is the star that rises in the east in the morning'.

Conversely, the unitization of associations in memory should make them less amenable to description using common nouns, as in 'Venus is the Morning Star'. Indeed, as this example illustrates, common nouns that themselves may have descriptive meaning, can be combined to form a proper name, where the descriptive value is diluted or may be lost completely. One may think of the many (old) places called *Newtown* in the English-speaking world or the famous Barcelona stadium *el Camp Nou* (literally 'the new field'). Compound proper names bear striking similarities to the novel (and often highly specific and evocative) common-noun compounds considered to be indicative of unitization processes (Haskins et al., 2008; Parks & Yonelinas, 2015). The fact that the UF-connected perirhinal cortex supports the encoding of such associations is suggestive that unitized memory may support the retrieval of proper names via the anterior temporal–prefrontal network.

We consider that available evidence supports a dual-process account whereby unitized (item-item or item-feature) versus non-unitized (item-item and item-context) encoding can support the association of proper names with individuating information relevant to unique entities. This still leaves open questions as to what individuating attributes might bias encoding towards unitized or non-unitized processes, and how these may give rise to divergent networks supporting retrieval. Here below we briefly explore evidence that the encoding of social and emotional information plays a prominent role in the unitization of information about unique individuals, enabled by UF connections from the OMPFC to the MTL. Importantly, the contribution of emotional information to the unitization process tends to support recollection supported by UF-connected regions rather than familiarity, thus enabling name retrieval. Conversely, the associations between less emotionally arousing stimuli tend to be encoded in a non-unitized manner alongside contextual information. As we have proposed above, this contextual encoding process supports the retrieval of proper names from posterior networks.

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3.3 The encoding of socio-emotional information supporting the subsequent retrieval of proper names

Activations of the amygdala during face-name encoding have been implicated in subsequent memory effects at retrieval (Sperling et al., 2003; Kirwan & Stark, 2004). There is extensive literature on amygdalar involvement in the processing of facial emotion (prominently, but not exclusively, negative emotions), attractiveness (including attractive and unattractive faces over neutral faces), and in making social judgements, such as evaluations of trustworthiness based on facial attributes (see e.g. Adolphs, Tranel, & Damasio, 1998; Morris et al., 1996; Adolphs, Tranel, Damasio, & Damasio, 1994; Tsukiura, 2012).

Dolcos, LaBar, and Cabeza (2004) showed that amygdalar activations increase during the encoding of emotional but not neutral images, aiding later retrieval. These activations correlated with those of other anterior MTL structures, most significantly the entorhinal cortex and the anterior hippocampus. Posterior portions of the hippocampus and parahippocampal gyrus were most significantly activated for neutral stimuli (see also Luck, Leclerc, & Lepage, 2014 for anterior–posterior MTL divergence in emotional-versus-neutral associative encoding). Within the amygdala, activation for emotional encoding has been shown to occur primarily in its basolateral aspect, which connects to fronto-temporal regions, likely via the UF (Dolcos, LaBar, and Cabeza, 2004; Von Der Heide et al., 2013).

In Kensinger and Schacter's (2006) item-source encoding study, amygdalar activations were associated with subsequent memory for both positive and negative emotional word and picture stimuli, but not for neutral stimuli. The entorhinal cortex was activated for items subsequently remembered, regardless of emotional content, while posterior parahippocampal and hippocampal activations correlated with subsequent memory for items and task contexts in which they were presented.

In the prefrontal lobe, the UF-connected OMPFC has been implicated in automatic processing for facial attractiveness, interpreting the friendliness of facial expressions (O'Doherty et al. 2003), and other processes of affective evaluation during impression formation (Mitchell, Neil Macrae, and Banaji 2005). Functional connectivity between the OFC and hippocampus, as well as increased activations in

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these regions at encoding, have been shown to predict increased subsequent memory for attractive over neutral or unattractive faces (Tsukiura & Cabeza, 2011). In their review of functional imaging literature, Amodio and Frith (2006) concluded that the anterior medial prefrontal cortex processes perceptual information relevant to people, including observations of social interactions and judgements about the appropriateness of behavior.

Overall, an extensive literature points to bilateral interactions between the OMPFC, amygdala, anterior medial temporal cortex, and ultimately, the ATL in the encoding of social and emotional information. These same regions are also prominently activated at retrieval (for review see Dolcos et al., 2017). The ATL has been shown to be selectively responsive to the learning of information about people over information about tools and buildings, suggesting domain specificity for processing social information (Simmons, Reddish, Bellgowan, & Martin, 2010). In the same study, "resting state" functional connectivity of the ATL pointed to prominent connections with the medial prefrontal cortex, amygdala, and the social cognition network more broadly (including posterior midline regions), as well as regions implicated in domain general processing, such as the hippocampus, perirhinal cortex, and inferior prefrontal cortex (Simmons et al., 2010; see also Simmons & Martin, 2012).

Olson, Plotzker, and Ezzyat (2007) propose that the right temporal pole is a hub for highly-processed sensory inputs combined with social and emotional responses to those inputs. One possibility is that the right temporal pole acts as a "storehouse" (ibid.) of conceptual information related to people, with storage in the left temporal pole being primarily lexical rather than conceptual (thus supporting the retrieval of proper names). Alternatively, similar person-related conceptual information may be stored in both hemispheres, with only leftward lesions affecting language processes leading to deficits in lexical retrieval (see Gainotti 2017).

UF dysfunction is associated with deficits and disorders that underscore its crucial role in social and emotional cognition. These include associations with neuropsychiatric disorders (psychopathy, antisocial personality disorder, and deficit schizophrenia), abnormal personality traits related to these disorders (emotional detachment, diminished emotional range, restricted affect, diminished social drive,

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and antisocial behaviors), and socio-emotional impairments emergent in neurodegenerative diseases, paralleling with those of neuropsychiatric disorders (monotone voicing, loss of facial expressions, loss of empathy, diminished affect, withdrawal) (Craig et al., 2009; Motzkin et al., 2011; Anderson, Bechara, H. Damasio, Tranel, & A. R. Damasio, 1999; Harlow, 1993; Motzkin et al., 2011; Thiebaut de Schotten et al., 2015; Kitis et al., 2012; Von Der Heide et al., 2013).

Activations in the OMPFC and hippocampus at encoding, as well as functional connectivity between these regions, have been shown to correlate with increased subsequent memory for names that had been associated with smiling faces over those associated with a neutral expression. Furthermore, activity and functional connectivity between these regions and the anterior parahippocampal gyrus was associated with improved retrieval performance (Tsukiura & Cabeza, 2008). Within healthy populations, variability in the connectivity of UF from the orbitofrontal cortex (OFC) to the ATL has been shown to predict proficiency in learning face-name associations (Metoki, Alm, Wang, Ngo, & Olson, 2017).

Finally, and importantly for the dual-process account presented here, there is strong evidence that the encoding of emotional information influences whether associated stimuli become unitized in memory or not (see Chiu, Dolcos, Gonsalves, & Cohen, 2013 and Murray & Kensinger, 2013 for reviews). The effects of emotion on item and associative memory often vary according to the nature of stimuli presented, the nature of associations between items, the contexts in which they are presented, how emotionally arousing they are, and whether they are positively or negatively valenced (Dolcos et al., 2017). Nonetheless, there is a general tendency for emotionally arousing stimuli and their constituent features (item-feature unitizations) to be better remembered than are non-emotional stimuli, and that this potentiates recollection rather than familiarity. This effect increases over time and often involves interaction between the amygdala and anterior (para)hippocampal regions (Mather, 2007; Murray & Kensinger, 2013; Yonelinas & Ritchey, 2015).

This last point is especially important given that proper-name retrieval requires mnemonic resources to support explicit recollection, while unitization had been shown to predominantly support

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subsequent familiarity judgements. The encoding of emotional information as part of unitized associations appears to tip the balance in favor of recollection over familiarity. Increased anterior parahippocampal and OMPFC activations for successful recollection of smiling face-name associations (Tsukiura & Cabeza, 2008) suggest that the retrieval advantage conferred by emotional encoding may be due to unitization processes dependent on the UF-connected network. Conversely, emotion often has null or negative effects on the encoding of contextual details (Yonelinas & Ritchey, 2015). When emotional items are presented as part of a scene, the details of these items are often encoded at the expense of peripheral contextual details, while the opposite is true for neutral items, which are often remembered better when contextually associated (Kensinger & Schacter, 2006; Mather, 2007).

We propose that socio-emotional information, readily derived from the facial (and behavioral) expressions and characteristics of unique individuals, is encoded in a unitized manner alongside proper names. These unitized memories support the subsequent retrieval of names from the UF-connected anterior temporal–prefrontal network. We propose that this unitization process is potentiated by the presentation or utterance of a name concurrently with the encoding of visual information for unique entities. Furthermore, we propose that the hippocampus and parahippocampal cortex enable non-unitized item-item and item-context encoding of less emotionally arousing information relevant to unique entities, supporting the subsequent retrieval of proper names from posterior networks.

3.4 Summary of evidence for dual encoding processes supporting subsequent network divergence in the retrieval of proper names

Naming deficits in neurodegenerative diseases point to the importance of the MTL in supporting the retrieval of recently encoded proper names. Motivated by this region's crucial role in the encoding of new memories, here we have reviewed evidence that multiple structures dispersed along the MTL's longitudinal axis are activated during the associative encoding of proper names and the faces of individuals they pick out. Structures prominently implicated in face-name encoding include the amygdala, entorhinal and perirhinal cortices, hippocampus, and parahippocampal cortex.

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Evidence points to anterior-versus-posterior divergence in the encoding processes supported by these structures: Activations of the anterior parahippocampal region are prominently implicated in the encoding of items and associations subsequently recognized as familiar, while hippocampal and posterior parahippocampal activations are more often implicated at encoding when item-item associations and contextual details are later recalled. Similarly, at retrieval, hippocampal and posterior parahippocampal regions are also regularly activated during item-context and item-item associative recall, while perirhinal activations are often associated with familiarity judgements. Anterior-versus-posterior divergence at retrieval extends beyond the MTL, including prominent activations at the temporo-occipito-parietal junction for recollection and anterior temporal and orbitofrontal activations for familiarity. These networks suggest a divergence in retrieval networks similar to that reviewed in section 2 for proper names.

However, given that the anterior network implicated in proper-name retrieval supports recall and not just familiarity, we have sought to detail the neural processes that underlie each of these behavioral phenomena. Strong evidence points to perirhinal activations in the encoding of unitized associative memories that subsequently support familiarity judgements, largely dependent on anterior temporal–prefrontal connections. Crucially, this UF-connected network also supports recollection of unitized memories, especially potentiated when emotional information is encoded as part of unitized associations. This emotionally supported unitization is enabled by interactions between the anterior parahippocampal gyrus, amygdala, OMPFC, and, possibly, the hippocampus. Indeed, emotionally expressive face-name associations are better remembered than those for neutral faces and names, with both encoding and retrieval of these associations showing increased activations in UF-connected regions. Non-unitized item-item associative, contextual, and non-emotional (neutral) encoding, is predominantly supported by the hippocampus and parahippocampal cortex. We propose that these encoding processes subserve the subsequent retrieval of proper names via activations of posterior cortical regions at the temporo-occipito-parietal junction.

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3.5 Dual encoding and retrieval processes in the light of selective proper-name anomias

Given that our exploration of encoding and retrieval networks is partly motivated by lesion evidence that the brain processes proper names in a category-specific manner, our model should be able to account for instances where proper-name anomias are almost total, while the retrieval of common nouns is broadly spared. Although the dual-process account provides relatively clear reasoning for instances — typical in the semantic dementia literature — where the loss of proper names patterns with that of common nouns, or where the retrieval of proper names alone tends to be partially disturbed, our model may have more difficulty where proper names are exclusively and extensively lost.

In the most clear-cut case of which we are aware (Semenza & Zettin, 1988), a patient (PC) following left parieto-occipital stroke, could not name any famous people, cities, countries, rivers, or mountains in an associative recall test. PC could freely recall just five relatives' names and five city names (including his home city) in the space of a minute. At times during assessment he was observed to be able to use the name of his native country (Italy) and to consistently recall the names of his wife and son. Under our model, such near total loss of proper names may be expected to result from damage to both fronto-temporal and temporo-occipito-parietal networks. Nonetheless, the ability to retrieve certain proper names of particular socio-emotional importance is consistent with partial sparing of fronto-temporal connections and/or retained anterior MTL integrity, allowing for the retention or relearning of proper names regularly encountered in daily life.

Another case of near global proper-name anomia (LS), described by the same authors, resulted from left fronto-temporal lesion (Semenza & Zettin, 1989). LS's retrieval of geographical names was better relative to PC, consistent with the prediction of our model that the sparing of the temporo-occipito-parietal region should allow for comparatively better retrieval of proper names of lesser socio-emotional importance. Seemingly inconsistent with our model is the fact that LS was also better at retrieving relative's names than PC. As the authors note, however, these names had to be relearned subsequent to the lesion and during the months before testing, consistent with retained structural

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integrity and connections of the anterior MTL, allowing for the encoding of recently encountered names.

Perhaps more challenging to our account is the fact that, in the first case study, PC could recall detailed world knowledge in the form of descriptions about the unique entities he could not name. Our model predicts that posterior damage is more likely to correlate with loss of both common nouns and proper names. Nonetheless, as the authors suggest, PC's deficits point to problems in accessing the output lexicon, connecting to phonological or graphemic form (Semenza & Zettin, 1989). While there is no evidence that the output lexicon is categorically organized in a manner comparable to conceptual or semantic information (see Semenza, 2009), PC's deficits suggest that a category-specific lexical access mechanism may have been damaged (Semenza & Zettin, 1989). Relative sparing of the left posterior temporal lobe may explain the retention of PC's conceptual knowledge associated with unique entities, while access to output systems for proper-name use from this posterior region may have been all but completely lost.

3.6 A model for the encoding and retrieval of proper names in the ventral semantic stream

Accounts of left UF function based largely on early functional imaging studies of language processing had proposed this tract to be involved in basic syntactic processing (Friederici, 2011; Friederici, Bahlmann, Heim, Schubotz, & Anwander, 2006; Friederici & Gierhan, 2013), while more recent accounts (e.g. Friederici & Singer, 2015) propose there to be a dual ventral stream for semantics supported by white-matter tracts connecting prefrontal and temporal lobes. This raises questions as to which semantic processes are subserved by the UF, ILF, and IFOF.

The evidence we have reviewed here suggests one possible answer, with the left UF — connecting the OMPFC, amygdala, and the anterior MTL — enabling unitized proper-name encoding and retrieval, and bilaterally supporting social and emotional processing. Meanwhile the ILF and IFOF are likely crucial for relaying visual information from the occipital lobe to the MTL and OMPFC, respectively, before UF connections integrate these with socio-emotional information. ILF and IFOF connections to the posterior temporo-occipito-parietal region are also likely to support the retrieval of both proper

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names and common nouns. This may include lexical (indeed sentential) associations between proper names and common nouns that provide contextual information (for example definite descriptions, discussed below). We propose that such associations are enabled by earlier item-item, item-context, and neutral (non-emotional) encoding processes in the hippocampus and parahippocampal cortex. This model is summarized in Figure 1.

4. Conclusion: Implications of the dual-process account for classical theories of naming and reference, and outstanding issues for further inquiry

Here below we briefly explore the possibility that the dual-process account of proper-name encoding and retrieval can inform long-standing debates about the meanings that these lexical items pick out. We consider three of the most influential perspectives on the matter here.

4.1 Classical theories in the light of evidence for dual processes in the encoding and retrieval of proper names.

A prominent view of the semantics of proper names, associated with John Stuart Mill, takes it that they directly refer to unique entities in the world. In Mill's own words, proper names "denote the individuals who are called by them … are attached to the objects themselves, and are not dependent upon the continuance of any attribute of the object" (Mill, 1858, pp. 21-22; see also Kripke, 1972). On Mill's account, naming a unique entity should depend on neural structures necessary for the perception of that entity, the association perceptual information with lexical or phonological form, and the committal of this association to memory, allowing for subsequent retrieval. Mill's proposal is most consistent with evidence that proper names are encoded in a unitized manner alongside information derived from unique entities.

However, this account seems inconsistent with evidence that UF–MTL connections encode socio-emotional evaluations and impressions with perceptual information about unique entities. There is evidence that these processes may be crucial for subsequent unitization-based recall of proper names. Socio-emotional encoding processes also suggest contributions to the meaning of a name that are

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internal to the speaker who uses it. This goes beyond the perceive–encode–associate–retrieve architecture that would better support Mill's theory of direct reference for proper names.

On the other hand, Gottlob Frege (1948) considered that proper names do not directly refer, but instead pick out a *sense* of an entity which can vary, roughly, according to the context in which it is presented, or perhaps the perspective from which it is perceived (for Frege, the entity's *mode of presentation*). Thus, the change in context makes it possible for Venus to be called the Morning Star when it appears in the east but the Evening Star when appearing in the west. Frege's argument that proper names, rather than being attached directly to the entity being named, instead pick out an external sense that is determined by context or perspective, shares certain aspects of both the unitized and item-context accounts of proper-name encoding and retrieval. On the one hand, the observation that contextual factors influence the meaning of a name parallels with evidence that item-context encoding can support proper-name retrieval. However, for Frege, the senses that proper names picked out were inherent in their meaning, which is distinct from the non-unitized associations that item-context memory encodes. If senses are considered to be meanings determined by perspective, this may be more compatible with evidence that information extracted from perceptual inputs is encoded in a unitized manner alongside proper names. Again, however, evidence that socio-emotional encoding makes an important contribution to the unitization process would suggest that senses are internal and variable according to the speaker who uses a name, rather than solely determined by external context.

Finally, influential accounts extending from the work of Bertrand Russell consider meanings of proper names to be equated with descriptions, sets of descriptions, or sets of properties of unique entities (Russell, 1911; Searle, 1958). Thus, a description such as 'The independent senator from Vermont', which picks out a unique entity, could (at least partly) be equated with the meaning picked out by the proper name *Bernie Sanders*. Intriguingly, the detached contextual nature of non-unitized encoding, whereby the associations can be described using common nouns, has parallels with Russell's (1911) account that the meanings which proper names pick out can be equated with definite

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descriptions. This is underscored by evidence that posterior cortical regions support both proper-name and common-noun retrieval.

However, the contributions of socio-emotional encoding and unitization strongly suggest that definite descriptions cannot, on their own, account for the meanings that proper names pick out. When definite descriptions are converted into proper names (*the white house* versus *The White House*), this may be supported by the unitization of socio-emotional information in anterior regions.

4.2 Concluding remarks: Future directions for research into proper-name encoding and retrieval

Our proposal that distinct unitized versus non-unitized encoding processes drive the divergence of proper-name retrieval networks makes various predictions that can be experimentally tested. These include predictions of divergence in the associative encoding of proper names versus common nouns, and that both featural emotion and the (non-)concurrent presentation of stimuli should have differential effects on how proper names are associatively encoded. We briefly overview potential ways to test these predictions here below.

The potentiation of subsequent associative memory by emotion — shown to improve retrieval of smiling face-name associations, dependent on UF-connected regions (Tsukiura & Cabeza, 2008) — should be expected to diminish when names are presented non-concurrently with emotional faces. Where non-concurrent emotional face–name encoding is successful, this may be expected to activate the parahippocampal cortex, suggesting non-unitized encoding or non-attendance of emotional information. Qin et al. (2007) found such activations for non-concurrent neutral face–person name and neutral face–place name associations.

Our proposal that emotional face–proper name associations are particularly receptive to unitized encoding, aiding subsequent recall, also entails that associations a.) between emotional faces and common nouns, and b.) between proper names and individuating descriptions, should be less receptive, instead tending towards non-unitized encoding. While it is to be expected that associative memory for common nouns should be better than for proper names (McWeeny et al., 1987; G. Cohen, 1990), one could measure the effect of emotional facial expression, trustworthiness, or attractiveness

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on subsequent memory for concurrently and non-concurrently presented faces, names, occupations, or other common-noun descriptors such as possessions. Under our account, the potentiating effect of emotional arousal on subsequent memory would be expected to improve recall of concurrently presented faces and proper names to a greater extent than faces and common nouns, an effect that may increase over time (see Yonelinas & Ritchey, 2015).

The association of names with descriptions of people may be expected to differentially activate hippocampal and posterior hippocampal structures. Under a paradigm where emotional faces, names, and descriptions are presented both concurrently and non-concurrently with each other, our model predicts that encoding and retrieval of emotional face–name associations should depend on structures in the UF-connected network to a greater extent than other types of association. Subsequent memory is expected to be worst for proper nouns associated with non-concurrently presented faces. Where proper names can be successfully retrieved in such instances, this would be expected to depend to a greater extent on successful associations with common-noun descriptors, and less on emotionally arousing facial features. Retrieval in such instances should also be expected to differentially depend on the parahippocampal cortex and, as memories become better encoded, on temporo-occipito-parietal regions.

A related prediction of our model is that subsequent memory for concurrent face-name-voice associations should potentiate subsequent name retrieval due to the unitized nature of the stimuli, where a name, like a voice, may be encoded as a feature of an individual. The unitizing effect of using individuating voices is expected to increase where unique individuals are shown to utter their own names. Encoding and retrieval in these instances is expected to depend on the UF-connected network. Under our account, this effect should be greater for proper names than for face-voice-description associations, which we expect to comparatively resist unitization. A separate contrast for face-name-description associations could be made where a third-party voice ‘introduces’ the individual. We consider that use of auditory stimuli in these contrasts would increase the ecological validity for how face-name associations are typically made. If names indeed tend to be differentially encoded as features

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of individuals, emotional arousal should be expected to potentiate subsequent memory for proper names over descriptions, especially in cases where individuals introduce themselves.

Much of the evidence to support our model, including the manipulations suggested here to test it, are derived from face-name association paradigms. Faces transmit social and emotional signals perhaps more regularly and clearly than any other stimuli, and provide a relatively easy means to control for the influence of these signals on associative encoding. However, a potential criticism stemming from this same evidence is that our model may not extend beyond people's names to those for unique objects, places, or other entities.

Despite these reservations, evidence for similar left temporal pole activity for both landmarks and people's names (Grabowski et al., 2001), suggests that the influence of socio-emotional and unitized encoding may bear on all proper names. It has been shown that activations in the perirhinal cortex track subjects' cumulative lifetime experience with objects and object concepts (Duke, Martin, Bowles, McRae, & Köhler, 2017). This may be indicative of increasing unitization processes over time as a result of an object's perceived social relevance and/or the emotion it arouses. It is just such objects that one could expect to be named with a proper name.

An interesting paradigm to test the dual-encoding account for object or place names would be to measure the effect of previous experience with visual stimuli on subsequent memory for definite descriptions, indefinite descriptions, and proper names. Under our account, the effect of increased lifetime experience with an object or location should be expected, relatively speaking, to increase subsequent memory (including the duration of memories) for associated proper names more so than for associated descriptions, with indefinite descriptions showing the smallest effect of previous experience with the object. Conversely, associated descriptions should be better remembered than proper names when attached to recently encountered stimuli. Just as with the Baker/baker paradigm, one could contrast the use of proper names that take the form of capitalized definite descriptions with non-capitalized definitions (e.g. [The] New Harbor versus [the] new harbor).

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In terms of the philosophical questions that have interested us here, we do not expect that support or refutation of our model can reconcile age-old debates about how language and the mind interact with unique entities in the world. Nonetheless, we hope that the evidence presented here of how internal neural processes contribute to the meaning of a name may inform these philosophical issues. Similarly, we think that it should be interesting to neuroscientists that findings which have accumulated in distinct research streams over the past three decades point towards a dualism in the brain mechanisms for proper-name encoding and retrieval (unitized versus item-context associative) that parallel in many ways with dual conceptualizations in the philosophy of language (denotational versus descriptive) of how these lexical items pick out unique entities.

Declarations of interest:

None

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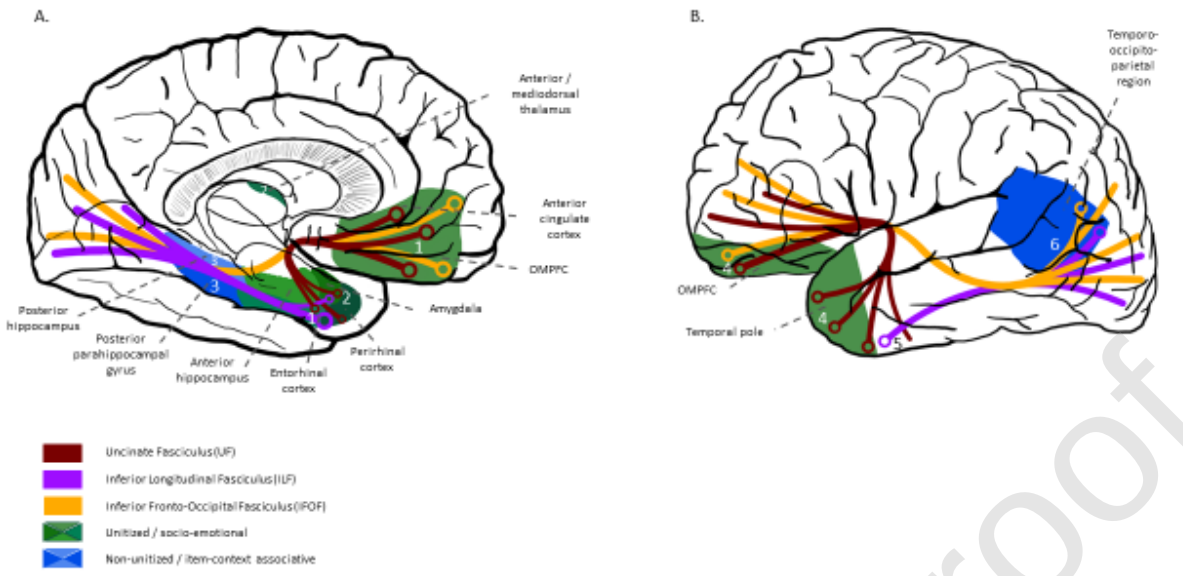
Figure Captions:

Figure 1. Illustration of networks related to proper-name encoding and retrieval:

A. Proper-name encoding: 1) The IFOF and ILF relay visual information from the occipital lobe to the orbital and medial prefrontal cortices (OMPFC) and anterior medial temporal lobe (MTL), respectively, where processing of social and emotional information relevant to unique entities occurs. 2) The medial UF, connecting both amygdala and OMPFC, integrates socially and emotionally processed information relevant to individuals, encoding this in a unitized manner via perirhinal and, possibly, entorhinal connections in the MTL. Specific object information, relayed by the ILF, may become processed in terms of its social and emotional relevance via the amygdala and OMPFC connections of the UF. The hippocampus is connected to these structures via the perforant path, and subserves both item-item unitization and non-unitized associative encoding. Anterior and mediodorsal thalamic nuclei engage these MTL regions to bind individuating and lexical information. 3) Non-unitized item-item and item-context associations are encoded via interactions of the hippocampus and parahippocampal cortex.

B. Proper-name retrieval: 4) UF connections between the OMPFC and temporal pole enable retrieval of proper names via unitized visual, auditory and socio-emotional information, encoded earlier through anterior MTL structures. 5) Lateral anterior temporal connections of the ILF terminate posteriorly to those of the UF, subserving the retrieval of information relevant to specific common nouns and definite noun phrases. Integration of this information with socio-emotional information in the anterior MTL may enable the retrieval of definite noun phrases as proper nouns from anterior polar areas. 6) Information encoded in the posterior temporal region, bordering parietal and occipital lobes, supports both common-noun and proper-name retrieval, enabled by previously encoded non-unitized item-item and item-context associative memories.

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