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Impaired assessment of cumulative lifetime familiarity for object concepts after left anterior temporal-lobe resection that includes perirhinal cortex but spares the hippocampus

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ABSTRACT

The ability to recognize the prior occurrence of objects can operate effectively even in the absence of successful recollection of episodic contextual detail about a relevant past object encounter. The pertinent process, familiarity assessment, is typically probed in humans with recognition-memory tasks that include an experimentally controlled study phase for a list of items. When meaningful stimuli such as words or pictures of common objects are employed, participants must judge familiarity with reference to the recent experimental encounter rather than their lifetime of autobiographical experience, which may have involved hundreds or thousands of exposures across numerous episodic contexts. Humans can, however, also judge the cumulative familiarity of objects concepts they have encountered over their lifetime. At present, little is known about the cognitive and neural mechanisms that support this ability. Here, we tested an individual (NB) with a rare left anterior temporal-lobe lesion that included perirhinal cortex but spared the hippocampus, who had previously been found to exhibit selective impairments in familiarity assessment on verbal recognition-memory tasks. As NB exhibits normal recollection abilities, her case presents a unique opportunity to examine potential links between both types of familiarity. In Experiment 1, we demonstrated that NB's impairment in making recognition judgments affects cumulative frequency judgments for exposure to concept names in a recent study episode. Experiments 2 and 3 revealed, with a task borrowed from the semantic-memory literature, that NB's impairments do indeed extend to abnormalities in judging cumulative lifetime familiarity for object concepts. These abnormalities were not limited to verbal processing, and were present even when pictures were offered as additional cues. Moreover, they showed sensitivity to concept structure as reflected in semantic feature norms; we only observed them for judgments on object concepts with high feature overlap. In Experiment 4, we found that an amnesic patient (HC) with previously established deficits in autobiographical recollection, due to a selective lesion of the extended hippocampal system, does not exhibit any abnormalities in assessing lifetime familiarity. Together, these findings provide support for a functional link between the assessment of recent changes in familiarity, as probed with experimental study-test paradigms, and cumulative lifetime familiarity based on autobiographical experience accrued outside the laboratory. They argue in favor of the notion that familiarity is closely related to the representation of concept knowledge, likely through computations in perirhinal cortex.

1. Introduction

The ability to recognize the prior occurrence of objects in the environment is critical to many aspects of adaptive behavior. There is a consensus in the psychological literature that recognition memory can operate effectively even in the absence of successful recollection of episodic contextual detail about a pertinent past object encounter (Yonelinas, 2002). The process that allows for recognition independent of episodic recollection is often referred to as familiarity assessment.

Familiarity is typically probed in humans with recognition-memory tasks that include an initial experimentally controlled study phase for a list of items. Familiarity-based responses are those in which an item is endorsed as studied, with no reported

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recovery of contextual detail about that study encounter. Critically, when meaningful stimuli such as words or pictures of common objects are employed, as is the case in the majority of published studies in cognitive neuroscience research on recognition memory (Eichenbaum et al., 2007; Kim, 2013), participants must judge familiarity with reference to the recent experimental encounter rather than with respect to their lifetime of autobiographical experience, which may have involved tens, hundreds, or thousands of exposures in many different episodic contexts. From this perspective, extant cognitive neuroscience research has primarily probed recent incremental changes in familiarity rather than absolute or cumulative levels (Bridger et al., 2014; see also Coane et al., 2011; Mandler, 1980). Humans can, however, also judge the cumulative familiarity of objects concepts (i.e., the concrete object that a word or picture refers to; Martin, 2015) they have encountered over their lifetime as the outcome of many learning episodes outside the laboratory. Such judgments show considerable consistency across participants in normative studies of concept knowledge, and are also known to have some external validity, as reflected in moderate correlations with objective word frequency (Cree and McRae, 2003; Moreno-Martínez et al., 2014; Schröder et al., 2012). At present, little is known about the cognitive and neural mechanisms that support this ability.

Cumulative familiarity judgments for object concepts acquired over a lifetime and familiarity-based responses in recognition-memory tasks for items from a studied list can be considered similar in that both require an assessment of prior item occurrence without any requirement to recover contextual information about a specific episodic encounter. Perhaps owing to this similarity, it has often been assumed that the recognition-memory paradigm can provide a model to understand lifetime familiarity that hinges on the effects of accumulated semantic knowledge (e.g., Atkinson and Juola, 1974). Whether this assumption is justified, however, is a question that can ultimately only be answered through systematic empirical investigation (see Mandler, 2008, for further discussion).

A well-known and robust empirical finding in cognitive psychology that addresses the relationship between cumulative lifetime and recent incremental changes in familiarity is the mirror effect in recognition memory. It refers to the observation that hit rates are typically higher, and false alarm rates are lower, for low frequency as compared to high-frequency words (Glanzer and Adams, 1990). It has been suggested that high-frequency lures are more often falsely recognized as 'old' because participants mistake familiarity associated with prior lifetime experience as familiarity based on a recent encounter (Greene, 1999; Joordens and Hockley, 2000; Reder et al., 2000). In support of this notion, for example, Reder et al. demonstrated, using the Remember-know paradigm, differential increases in 'know' responses for high as compared to low frequency lure words. Such findings suggest that, in phenomenological experience, it is not always apparent whether a stimulus feels familiar due to a recent laboratory exposure or due to frequent pre-experimental experience with it in daily life. As such, the effect could also hint at shared neural mechanisms.

There is a consensus in the neuroscience literature across rodents, non-human primates, and humans that recognition memory requires contributions of perirhinal cortex (PrC) in the medial temporal lobe (MTL; Brown and Aggleton, 2001; Murray et al., 2007; Squire et al., 2007; Suzuki and Naya, 2014). There is also considerable evidence to suggest that within the MTL, mechanisms that allow for familiarity assessment are, at least in part, distinct from those that support recovery of contextual detail about a specific recent item encounter (for reviews see Aggleton and Brown, 2006; Diana et al., 2007; Eichenbaum et al., 2007; Montaldi and Mayes, 2010; but see Squire et al., 2007). Although it remains contentious how best to characterize the unique functional contributions of different MTL structures, we note that a number of lesion studies have revealed dissociations in patterns of memory impairments that can be captured with the broad distinction between item-based familiarity assessment and episodic recollection (Aggleton et al., 2005; Bowles et al., 2010; Brandt et al., 2009; Horner et al., 2012; Jäger et al., 2009; Mayes et al., 2002; Tsivilis et al., 2008; Turriziani et al., 2008; Vann et al., 2009; Yonelinas et al., 2002; but see Cipolotti et al., 2006; Manns et al., 2003; Wais et al., 2006). Critically, it has been shown that anterior temporal lobe lesions that spare the hippocampus can produce deficits in familiarity assessment that leave recollection intact. We found this pattern of performance in an individual (patient NB) who underwent a rare tailored surgical resection of the left anterior temporal lobe for treatment of intractable temporal-lobe epilepsy that included PrC but spared the hippocampus (Bowles et al., 2007; Martin et al., 2011; see Brandt et al., 2016, Cohn et al. (2010), Davidson et al. (2006), Martin et al., (2012), for other patients with selective familiarity impairments). Furthermore, we reported that a stereotaxic surgical treatment for temporal-lobe epilepsy that is restricted to the hippocampus and amygdala can produce selective recollection impairments on the same task, and at the same level of overall recognition performance, as the familiarity impairment that was observed in NB (Bowles et al., 2010). This double dissociation provides particularly strong support for the notion that familiarity assessment in the study-test paradigm relies on brain mechanisms that are, at least in part, distinct from those that support recollection. However, these findings to not speak to any potential role of PrC in judgments of cumulative lifetime familiarity.

Recent evidence from functional neuroimaging research suggests that PrC is involved in processing of object concepts even in tasks that do not make explicit reference to any recent experimental encounter (Dew and Cabeza, 2011; Heusser et al., 2013; O'Kane et al., 2005; Voss et al., 2009; Wang et al., 2010, 2014), and even in paradigms that do not include any experimental study phase (Bruffaerts et al., 2013; Clarke and Tyler, 2014; Liuzzi et al., 2015). In the latter set of studies, multivariate pattern analyses have revealed that PrC carries information that allows for fine-grained distinctions among similar object concepts. Neuropsychological research in patients with focal temporal-lobe lesions has also demonstrated that the extent of damage to PrC predicts differential behavioral impairments in naming confusable objects with high semantic feature overlap (Wright et al., 2015; for similar evidence in neurodegenerative disease see Kivisaari et al. (2012)). Overall, these findings are part a growing body of research that points to an important role of PrC in disambiguating objects and object concepts with high perceptual or semantic feature overlap in task contexts other than classic recognition-memory tasks (see Clarke and Tyler, 2015; Graham et al., 2010, for review).

A recent functional neuroimaging study from our lab provides, to our knowledge, the first evidence that implicates left PrC in the assessment of cumulative lifetime familiarity for object concepts. We examined fMRI BOLD responses when participants judged cumulative lifetime familiarity of object concepts or when they judged the degree of recent laboratory exposure to the same type of stimuli. This study implicated left PrC in both types of judgements (Duke et al., submitted). Notably, PrC was the only brain region that tracked perceived levels of recent experimentally-based concept exposure with the typical decrease in BOLD signal that has been reported for old as compared to new verbal items in many prior studies (Daselaar et al., 2006; Dew and Cabeza, 2013; Henson et al., 2003) while tracking perceived cumulative lifetime familiarity with an increase in BOLD signal.

In the present neuropsychological study, we aimed to shed further light on the neural mechanisms that support assessment of cumulative lifetime familiarity with object concepts based on

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