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Effect of frontal lobe lesions on the recollection and familiarity components of recognition memory

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ABSTRACT

Single-process theories assume that familiarity is the sole influence on recognition memory with decisions being made as a continuous process. Dual-process theories claim that recognition involves both recollection and familiarity processes with recollection as a threshold process. Although, the frontal lobes of the brain play an important role in recognition memory, few studies have examined the effect of frontal lobe lesions on recollection and familiarity. In the current study, the nonverbal recognition memory of 24 patients with focal frontal lesions due to tumour or stroke was examined. Recollection and familiarity were estimated using the receiver operating characteristic (ROC) method. A secondary analysis was also conducted using standard signal detection theory methodology. Both analyses led to similar conclusions where only the familiarity component of recognition memory was impaired in frontal patients compared to healthy controls whilst the recollection-type (or variance ratio) processes remained intact.

There are two main theories to account for recognition memory: single-process (e.g. Dunn, 2004; Malmberg, Holden, & Shiffrin, 2004; McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997) and dual-process theories (e.g. Jacoby & Dallas, 1981; Mandler, 1980; Tulving, 1985; Yonelinas, 1994). Both theories attempt to account for the subjective experience of familiarity and recollection. Familiarity is thought of as a feeling that an item has been presented but no additional information can be retrieved about the episode itself. Recollection involves remembering particular details about the experience when encountering an item.

According to the single-process theories of recognition memory, decisions are based upon an item's position along a single dimension (e.g. Dunn, 2004; Malmberg et al., 2004; McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997). A signal detection view has been proposed where memory judgements are based on the comparison between the level on the dimension of the current item with a criterion. A recollection response is given when the memory strength of a test item goes beyond a high criterion. If the strength of a test item only surpasses a lower criterion, a familiarity response is given. Therefore, remember versus know judgments made by individuals reflect quantitatively different levels of confidence for the same memory trace or set of memory traces (e.g. Donaldson, 1996; Dunn, 2004; Malmberg et al., 2004; McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997).

However, the dominant view in the literature, at least until very recently (Wixted, 2007), have been the dual-process theories which claim that recollection and familiarity are functionally independent component processes, both of which are important for judging whether an item has already been experienced (Jacoby & Dallas, 1981; Mandler, 1980; Tulving, 1985; Yonelinas, 1994). Some authors believe that the hippocampus and anterior thalamus support recollection while the surrounding temporal cortex, including the perirhinal cortex and the medial dorsal thalamus supports familiarity (Brown & Aggleton, 2001; Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000; Verfaellie & Keane, 2002; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998; Yonelinas, 2002). Others suggest that recollection and familiarity both depend on the hippocampus and perirhinal cortex (e.g. Manns, Hopkins, Reed, Kitchener, & Squire, 2003; Squire & Zola, 1997; Wixted & Squire, 2004).

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The empirical data from patients with lesions in the medial temporal lobes are inconsistent as to whether recollection and familiarity are anatomically distinct. Some patients with bilateral hippocampal damage are reported to have selective deficits in recollection but not familiarity (MR: Bastin et al., 2004; YR: Mayes et al., 2004; KN: Aggleton et al., 2005). Certain group studies have also demonstrated recollection-specific deficits in patients held to have damage restricted to the hippocampus compared to patients with more extensive MTL lesions (Yonelinas, 2002; Turriziani, Fadda, Caltagirone, & Carlesimo, 2004). However, individual patients have also been reported who do not show sparing of familiarity following selective hippocampal damage. Patients with bilateral hippocampal lesions have been reported with significant reductions in both recollection- and familiarity-based recognition on tests using words and buildings as stimuli (JC: Bird, Shallice, & Cipolotti, 2007; VC: Cipolotti et al., 2006). In addition, patients with right hippocampal damage only have been shown to be impaired on both recollection and familiarity of topographical but not verbal and facial stimuli (RH: Bird et al., 2007). Also, in some group studies patients held to have bilateral hippocampal damage have been found to perform significantly more poorly than controls on both remember and know items using the remember/know procedure (Manns et al., 2003) and had lower recollection and familiarity estimates than controls using the ROC procedure (Wais, Wixted, Hopkins, & Squire, 2006; for reviews see Aggleton & Brown, 2006; Cipolotti & Bird, 2006).

Some memory models suggest that the frontal lobes also play an important role in recognition memory. However, it remains unclear whether the frontal lobes are involved in one or both of the recollection and familiarity processes. As the frontal lobes receive direct projections from the hippocampus and the medial portions of the thalamus, some authors argue that the frontal lobes are important for both components of recognition memory (Aggleton & Brown, 1999; Yonelinas et al., 2002). Others suggest that only recollection requires some additional processing by the frontal lobes (Davidson & Glisky, 2002; Knowlton & Squire, 1995; Tulving, 1989).

Most evidence for frontal lobe involvement has been provided by neuroimaging studies. Imaging data acquired during the encoding and retrieval phases of recognition memory has demonstrated that many regions of the prefrontal cortex are involved (for a review see Lepage, Ghaffar, Nyberg, & Tulving, 2000; Skinner & Fernandes, 2007). When contrasting brain areas associated with recollection and high confidence familiarity, Yonelinas, Otten, Shaw, & Rugg (2005) found recollection-related activation in the anterior medial frontal cortex (BA 10/32) and recognition confidence for non-recollected items positively correlated with left anterior (BA 10) and posterior prefrontal (BA 45/47) activation. More recently, Montaldi, Spencer, Roberts, and Mayes (2006) found activation in the bilateral inferior frontal gyrus (BA 47) and left medial frontal cortex (BA 10) when contrasting recollected scenes with strong familiarity. Increases in familiarity were associated with increases in the inferior frontal gyri and medial frontal cortex bilaterally. In a recent meta-analysis of the functional magnetic resonance imaging data, Skinner and Fernandes (2007) argued that both recollection and familiarity are related to right dorsolateral prefrontal activation, but recollection involves additional prefrontal activity in BA 6, 8 and 10. These results provide evidence for the involvement of the frontal regions in both recollection and familiarity, albeit different frontal regions.

The empirical data from patients with frontal lobe lesions are sparce. Earlier studies suggested that patients with focal frontal lesions do not demonstrate impairments in recognition memory (Janowsky, Shimamura, & Squire, 1989; Jetter, Poser, Freeman, & Markowitsch, 1986; Milner, Corsi, & Leonard, 1991; Stuss & Benson, 1984). More recently, studies have reported that recognition memory is affected, albeit with small effects. In particular, frontal patients can produce significantly higher false alarm rates on recognition memory tasks (Alexander, Stuss, & Fansabedian, 2003; Delbecq-Derouesne, Beauvois, & Shallice, 1990; Rapcsak, Polster, Glisky, & Comer, 1996; Rapcsak et al., 1998; Schacter, Curran, Gallucio, Milberg, & Bates, 1996; Swick & Knight, 1999). For example, in a study comparing recognition memory abilities of patients with frontal and patients with hippocampal lesions, Swick and Knight (1999) reported a double dissociation between the two patient groups. While the hit rates of the patients with unilateral frontal lesions were similar to controls, the patients produced significantly more false alarms. In contrast, while the hippocampal patients had a comparable false alarm rate to controls, their hit rate significantly declined as the retention interval increased. It has been suggested that this increase in false alarms reported in frontal patients is due to an over reliance on general characteristics common to both targets and distractors (Curran, Schacter, Norman, & Galluccio, 1997; Schacter et al., 1996). Therefore, distractors will appear familiar to frontal patients and they will report that the item has been presented before when in fact it has not. This would suggest that impaired recognition, in at least some frontal patients, may be due to deficits in familiarity rather than recollection processes.

To our knowledge, only one study in the neuropsychological literature has examined the effects of focal prefrontal lesions on recollection and familiarity (Duarte, Ranganath, & Knight, 2005). In this study, patients with unilateral frontal lesions performed only a recognition memory task employing meaningful objects. The stimuli were presented in either the left or right visual field and were considered as being contralesional or ipsilesional, depending on the patient's lesion site. Estimates of recollection and familiarity were obtained using the remember/know procedure. Frontal patients' estimates of familiarity were significantly reduced compared to healthy controls but only when items were presented in the contralesional visual field. In contrast, estimates of recollection remained intact. This study suggests that the frontal lobes are critical for the familiarity, but not necessarily the recollection component of recognition memory.

Further indirect evidence showing a similar pattern of results was reported by Davidson, Anaki, Saint-Cyr, Chow, & Moscovitch (2006) who examined recollection and familiarity in Parkinson's disease (PD) patients. PD patients have been reported to perform similarly to focal frontal patients on tests of executive abilities and memory (see Bondi & Troster, 1997; McPherson & Cummings, 1996; Owen, 2004; Prull, Gabrieli, & Bunge, 2000; Taylor, Saint-Cyr, & Lang, 1990; Zgaljardic, Borod, Foldi, & Mattis, 2003). Using both the remember/know and process-dissociation procedure (PDP) procedures to estimate familiarity and recollection, Davidson et al. (2006) found a selective reduction in familiarity but not recollection in PD patients. These two studies suggest that it is the familiarity component rather than the recollection component of recognition memory that is impaired as a result of frontal lobe lesions.

The aim of the current study was to investigate within the context of the dual-process model further the contribution of recollection and familiarity processes in terms of nonverbal recognition memory in a group of patients with focal frontal lesions. According to previous neuropsychological data, we predicted that frontal patients would have reduced familiarity, but not recollection, estimates. The main difference between the current study and that of Duarte et al. (2005) is the method used to extract the recollection and familiarity estimates. Duarte et al. (2005) used the remember/know experimental paradigm to estimate recollection and familiarity. However, this procedure relies upon introspective processes where individuals must state whether they have a clear sense of re-experiencing the item or simply know that they