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Qualitatively different memory impairments across frontal lobe subgroups

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Abstract

Recall impairments in patients with lesions to the prefrontal cortex (PFC) have variously been attributed to problems with organisation at encoding, organisation at retrieval and monitoring at retrieval. Neuroimaging and recent theoretical work has associated the left lateral PFC with organisation and strategy production at encoding, and the right lateral PFC with organisation, error detection and monitoring at retrieval. However few lesion studies have been anatomically specific enough to test the direct predictions made by this work. Proactive interference, response to prompting, monitoring and organisational strategies were examined in 34 patients with frontal lobe lesions and 50 healthy controls using a structured verbal recall task, and the fractionation of deficits according to specific frontal lesion site was explored. Recall impairments were observed in the Right Lateral and Medial frontal subgroups. The Medial recall impairment was unaffected by manipulations at encoding or retrieval and was attributed to a "pure" memory deficit arising from disruption of the limbo-thalamic system. The Right Lateral recall impairment was ameliorated by the provision of prompts at retrieval, indicating a strategic retrieval deficit. This intervention also resulted in an unusual pattern of intrusions, namely an increase in proactive interference responses compared with extra-list intrusions. However contrary to predictions no monitoring impairment was found. We offer two explanations for the pattern of performance in the Right Lateral group: failure of a right lateralised error detection and checking system, or an impairment in the active uncued initiation of a supervisory operation.

Keywords: Frontal lobes; Memory; Executive function; Proactive interference; Monitoring

1. Introduction

Damage to the frontal lobes does not result in the kind of severe amnesic syndrome typical of lesions to the temporal or diencephalic structures. However there is a large body of evidence suggesting that it may lead to a range of more subtle impairments of memory, particularly in recall tasks (Dimitrov et al., 1999; Janowsky, Shimamura, Kritchevsky, & Squire, 1989; Jetter, Poser, Freeman, & Markowitsch, 1986; Shimamura, Janowsky, & Squire, 1991; Wheeler, Stuss, & Tulving, 1995). Recall tasks are relatively effortful compared to recognition tasks, requiring the participant both to initiate an effective search in memory and to evaluate the products of this search. Therefore these deficits are thought to be secondary to impairments in frontally located supervisory processes, rather than being pure memory deficits.

1.1. Evidence from lesion studies

Recall impairments in frontal lobe damaged patients have been attributed to difficulties in employing effective strategies at either encoding or retrieval. Several studies have reported that frontal patients tend not to spontaneously categorise to-be-remembered material or use other top-down processes to aid encoding (Incisa della Rochetta, 1986; Hirst & Volpe, 1988). Kopelman and Stanhope (1998) have also reported that the recall of frontal patients (in contrast to diencephalic and temporal lobe amnesics) can be improved if semantically organised rather than unrelated word lists are used, externally providing the organisation that they are unable to impose subjectively. Several other groups have reported similar results. Gershberg and Shimamura (1995) found that their frontal patients benefited

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from strategy instructions at both the study stage and at the test stage, implying that they had deficits in implementing organisational strategies at encoding and in implementing strategic processes at retrieval. Strategy deficits at retrieval in the form of impaired pair frequency have also been reported by Eslinger and Grattan (1994), Gershberg and Shimamura (1995) and Vilkki, Servo, and Surma-Aho (1998), and Incisa della Rochetta and Milner (1993) reported an improvement in recall when retrieval cues were externally provided, especially amongst left frontal patients.

Most lesion studies have used either an undifferentiated "frontal" group (Gershberg & Shimamura, 1995; Hirst & Volpe, 1988; Kopelman & Stanhope, 1998), or at best have compared left frontal to right frontal subgroups (Incisa della Rochetta, 1986; Incisa della Rochetta & Milner, 1993; Vilkki et al., 1998). However more anatomically specific results have emerged from groups using functional lesion localisation techniques to assess whether different deficits might follow lesions to different subregions of the frontal lobe. Stuss et al. (1994), for example, have reported that patients with left frontal (particularly left dorsolateral) damage had the most severe recall impairments in a list learning task. More recently Alexander, Stuss, and Fansabedian (2003) confirmed marked verbal free recall deficits in patients with posterior left dorsolateral lesions, but also in those with posterior medial frontal lesions, hypothesised to result from direct disruption of the memory system arising from loss of cholinergic projections to the hippocampus.

In addition to reduced veridical recall, patients with frontal lobe damage have frequently been reported to be abnormally sensitive to proactive interference, and to produce high rates of intrusions in recall tasks (Baldo, Delis, Kramer, & Shimamura, 2002; Daum & Mayes, 2000; Delbecq-Derouesne, Beauvois, & Shallice, 1990; Melo, Winocur, & Moscovitch, 1999; Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995). However patient studies using more detailed lesion localisation procedures have failed to find any intrusion effects in their frontal groups (Alexander et al., 2003; Stuss et al., 1994) so the anatomical specificity of intrusion effects is not known. Stuss et al. (1994) did however report a specific deficit in patients with right lateral frontal lesions, who produced excess repetitions in their recall. This pattern of responding was attributed to an impairment in monitoring the output of recall, which prevented the patients from editing out words they had already recalled. Monitoring impairments have been associated with the production of false alarms in recognition memory tests (Budson et al., 2002; Curran, Schacter, Norman, & Gallucio, 1997; Delbecq-Derouesne et al., 1990; Melo et al., 1999; Schacter, Curran, Gallucio, & Milberg, 1996; Swick & Knight, 1999; Verfaillie, Rapscak, Keane, & Alexander, 2004) therefore right lateral monitoring impairments may also be related to the production of intrusions in recall.

1.2. Evidence from neuroimaging

Convergent with the patient findings, imaging studies of memory almost always show activation of the prefrontal cortex (PFC, see Fletcher & Henson, 2001, for a review). However for technical reasons related to movement artefacts, research in fMRI has tended to concentrate on recognition rather than recall. In general, greater left than right frontal activation is associated with encoding tasks, and greater right than left frontal activation is associated with retrieval tasks (the Hemispheric Encoding/Retrieval Asymmetry model: Habib, Nyberg, & Tulving, 2003; Nyberg, Cabeza, & Tulving, 1996; Shallice et al., 1994; Tulving, Kapur Craik, Moscovitch, & Houle, 1994).

Left prefrontal activation at encoding has most often been attributed to the retrieval of information from semantic memory which enables "deep" encoding to take place (Baker, Sanders, Maccotta, & Buckner, 2001; Henson, Rugg, Shallice, Josephs, & Dolan, 1999a; Wagner et al., 1998; Wig, Miller, Kingstone, & Kelley, 2004). More specifically this left prefrontal activation, and left *dorsolateral* activation in particular, has been associated with organisation of material at encoding on the basis of semantic relations or attributes (Fletcher, Shallice, & Dolan, 1998; Savage et al., 2001; Wagner, Maril, Bjork, & Schacter, 2001), a task at which patients with frontal lobe lesions are impaired.

Right prefrontal activation has been associated with retrieval success, or the adoption of a retrieval "mode" (Lepage, Ghaffar, Nyberg, & Tulving, 2000; Nyberg et al., 1996; Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1997; Wagner, Desmond, Glover, & Gabrieli, 1998). More specifically, one component of this right prefrontal activation, and particularly right *dorsolateral* prefrontal activation, is hypothesised to reflect monitoring and checking of the products of a memory search (e.g. Cabeza, Locantore, & Anderson, 2003; Fletcher, Shallice, Frith, Frackowiak, & Dolan, 1996; Fletcher, Shallice, Frith, Frackowiak, & Dolan, 1998; Gabrieli, 1998; Henson, Shallice, & Dolan, 1999b; Shallice, 2001). In support of this, ERP studies have provided evidence of a late onsetting right frontal positivity in recognition tasks that follows ecphory, and this has been attributed to post-retrieval monitoring (see Allan, Wilding, & Rugg, 1998, for a review).

1.3. Shallice's error detection and checking hypothesis

Shallice (2006) has assimilated this lesion and neuroimaging evidence in proposing that the Supervisory System (the prefrontal system which controls action in non-routine situations; Norman & Shallice, 1980, 1986) may be fractionated into anatomically separable subsystems, including a left dorsolateral system which controls strategy production by means of top-down selection of schema (for example the semantic organisation of word lists), and a right dorsolateral system in charge of non-evident error-detection and checking (for example the monitoring functions discussed above). Shallice (2001, 2006) has specified the error detection, checking and monitoring functions of the right dorsolateral system by proposing that it comes into play under three conditions.

(i) *When competing stimuli are likely to lead to capture errors*. In memory paradigms, proactive interference provides the best test of the ability to reject plausible alternatives and avoid capture errors. Henson, Shallice, Josephs, and Dolan (2002), in an fMRI study, reported right dorsolateral PFC