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The posterior parietal cortex in recognition memory: A neuropsychological study

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Abstract

Several recent functional neuroimaging studies have reported robust bilateral activation (L > R) in lateral posterior parietal cortex and precuneus during recognition memory retrieval tasks. It has not yet been determined what cognitive processes are represented by those activations. In order to examine whether parietal lobe-based processes are necessary for basic episodic recognition abilities, we tested a group of 17 first-incident CVA patients whose cortical damage included (but was not limited to) extensive unilateral posterior parietal lesions. These patients performed a series of tasks that yielded parietal activations in previous fMRI studies: yes/no recognition judgments on visual words and on colored object pictures and identifiable environmental sounds. We found that patients with left hemisphere lesions were not impaired compared to controls in any of the tasks. Patients with right hemisphere lesions were not significantly impaired in memory for visual words, but were impaired in recognition of object pictures and sounds. Two lesion–behavior analyses – area-based correlations and voxel-based lesion symptom mapping (VLSM) – indicate that these impairments resulted from extra-parietal damage, specifically to frontal and lateral temporal areas. These findings suggest that extensive parietal damage does not impair recognition performance. We suggest that parietal activations recorded during recognition memory tasks might reflect peri-retrieval processes, such as the storage of retrieved memoranda in a working memory buffer for further cognitive processing.

Keywords: Memory; Parietal; Stroke; Recognition; Lesion study; CVA; Familiarity

The posterior parietal cortex (PPC) does not feature in standard accounts of brain substrates of the encoding, consolidation, or retrieval of long-term, declarative memory (Squire, Stark, & Clark, 2004). Nevertheless, in recent years a growing body of evidence has accumulated suggesting a parietal role in long-term memory processes. Event-related potentials (ERP) studies of brain activity during the retrieval phase of recognition memory tasks have reported left-lateralized positivity recorded at temporo-parietal sites, in the interval between 400 and 800 ms post stimulus onset, greater for correctly recognized words than for correctly rejected new words, and therefore sometimes called the "retrieval success effect" (Rugg, 1995). This ERP component has also been called the "parietal old/new effect" (e.g., Maratos, Allan, & Rugg, 2000) or the "episodic memory (EM) effect" (e.g., Friedman & Johnson, 2000).

At first, this effect was believed to reflect memory-related activations of the medial temporal lobe (MTL) (Rugg, Schloerscheidt, Doyle, Cox, & Patching, 1996), which was then known on the basis of lesion studies to be differentially implicated in memory for words (affected more by left MTL lesions) and pictures (affected more by right MTL lesions; Milner, 1972). Schloerscheidt and Rugg (1997) tested this hypothesis by examining the old/new effect for pictures, which unlike the effect of words initially employed as stimuli was expected to have a more bilateral distribution. Contrary to this prediction, the parietal old/new effect was left-lateralized whether elicited by words or pictures (Schloerscheidt & Rugg, 1997; for a different view, see Mecklinger, 1998). These data raised the possibility that the old/new effect, as recorded on the scalp over temporo-parietal areas, does not directly reflect MTL activations, but rather other activations that are episodic memory retrieval-related and generalized across material types.

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Implementation of fMRI methods in the study of retrieval enabled higher spatial resolution for the examination of the aforementioned left parietal old/new effect. Such studies have consistently shown an old/new effect or "retrieval success effect" in the lateral and medial parietal cortex, as well as in anterior dorsal and ventral prefrontal cortex and, less consistently, the medial temporal lobe (reviewed by Rugg & Henson, 2002). These findings add weight to the hypothesis that the observed ERP scalp distribution is generated in the immediately underlying parietal cortex, and it is tempting to assume that the effects observed with the two methods are neuroanatomically and functionally equivalent (Rugg, 2004). However, even if such memory-related activations are found in parietal cortex, it remains unclear what memory processes they might reflect. Possibilities include pre-retrieval attentional cognitive processes, actual retrieval of information ("ecphory"; Tulving, 1983), or post-retrieval utilization of retrieved information, among many others (Wagner, Shannon, Kahn, & Buckner, 2005).

ERP and fMRI old/new effects or "retrieval success effects" in PPC are not readily reconciled with traditional theories of PPC function that emphasize processes associated with spatial attention and motor intention. This raises the possibility that either spatial or motor processing differences confounded retrieval task designs for which the retrieval success effect was observed, so that the effect might not be directly related to mnemonic processes. In a series of three fMRI experiments, Shannon and Buckner (2004) addressed these issues. In the first experiment, they showed that the retrieval success effect occurs bilaterally, not only for visual stimuli (object pictures), but also for binaurally presented sounds, which do not require focus of visuospatial attention. They concluded that this effect is independent of cue modality and probably does not reflect pure visuospatial attention-related cognitive processes. In a second experiment, they addressed the argument that activity in these regions reflects response-related motor intention through manipulations of response procedures, and found that the old/new effect remains as is, whether the participant were instructed to respond only to old stimuli, only to new stimuli, or to respond both to old and new stimuli. In a third experiment, they showed stronger parietal activations for deeply encoded words (i.e., those studied in an encoding task requiring relating to the semantic features of the words) than for words that were subject to shallow encoding (on which orthographic judgments were made at study). Since that distinction is widely reported to affect retrieval, the implication is that the differential activation represents a mnemonic effect (Shannon & Buckner, 2004).

This study and others (reviewed by Wagner et al., 2005) appear to provide support for the contention that the parietal lobes play an integral role in memory processes, even for simple recognition tasks. More recently, it has been reported that in the absence of task, stimuli, or explicit mnemonic demands, robust correlations were observed between fMRI-assessed activity in the hippocampal formation and several parietal regions (including precuneus, posterior cingulate, retrosplenial cortex, and bilateral inferior parietal lobule). This was interpreted as supporting the mnemonic role of those parietal areas (Vincent et al., 2006). Nevertheless, EEG and fMRI provide only indirect evidence for the neuroanatomical substrates of memory, because they can only reveal correlations between performance and activations, but not the necessity of such regions for the processes in question (Müller & Knight, 2006). While indirect evidence continues to accumulate for parietal involvement in recognition memory, direct evidence seems to paint quite a different picture. The vast majority of humans who have lesions to posterior lateral parietal sites (due to stroke, trauma or disease) do not seem to suffer from amnesia (in contrast to a few case studies of "retrosplenial amnesia", in which medial parietal areas are affected, e.g. Saito, Kimura, Minematsu, Shiraishi, & Nakajima, 2003; Valenstein et al., 1987; Yasuda, Watanabe, Tanaka, Tadashi, & Akiguchi, 1997). Furthermore, Rossi et al. (2006) recently reported applying repetitive transcranial magnetic stimulation (rTMS) to interfere with left or right parietal regions during encoding or retrieval stages of a recognition memory task. In the lower intensity condition, they found no significant reduction in performance relative to baseline, and at the higher intensity found only a generalized impairment that did not distinguish between application of rTMS to parietal areas and sham application. The authors conclude that the posterior parietal areas examined are not essential for recognition memory, and suggest that parietal activations observed in other studies could be due to additional brain processes that are simply associated with, but are not crucial for, the memory challenge (Rossi et al., 2006).

The neuropsychological study reported here was conducted with the aim of further clarifying the issue of parietal contributions to long-term memory. We tested recognition memory performance of right and left hemisphere cerebro-vascular accident (CVA) patients whose lesions encompassed posterior parietal areas, on tasks that elicited activation in PPC areas in fMRI studies (Shannon & Buckner, 2004), and thereby assessed the PPC contributions to those types of memory tasks. We found that patients with left hemisphere lesions were not impaired compared to controls in any of the tasks. Patients with right hemisphere lesions were not significantly impaired in memory for visual words, but were impaired in recognition of object pictures and sounds. Two types of analysis, namely, lesion–behavior correlations and voxel-based lesion symptom mapping (VLSM) analysis did not reveal significant parietal contributions to those recognition memory impairments, but rather implied that these impairments resulted from damage outside the parietal lobes.

1. Methods

1.1. Participants

1.1.1. Patients

20 first incident CVA (cerebro-vascular accident: ischemic or hemorrhagic) patients between the ages of 26–82 participated in this study. The patients were recruited during their hospitalization in Loewenstein Rehabilitation Hospital, Raanana, Israel. All patients provided informed consent to participate in the study, which was performed using a protocol approved by the human subjects research committee of the Loewenstein Rehabilitation Hospital, in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Patients were included in the study only if they did not suffer from psychiatric or prior neurological disorders, did not use psychotropic drugs, and their language and cognitive status enabled full comprehension of the task requirements. For three patients (1 RHD: TC; 2 LHD: MM, YE), although initial radiological assess-