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Neuropsychologia 45 (2007) 2428–2438

NEUROPSYCHOLOGIA

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Recognition memory for faces and scenes in amnesia: Dissociable roles of medial temporal lobe structures

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Received 8 September 2006; received in revised form 2 April 2007; accepted 3 April 2007
Available online 13 April 2007

Abstract

The relative contributions of the hippocampus and the perirhinal cortex to recognition memory are currently the subject of intense debate. Whereas some authors propose that both structures play a similar role in recognition memory, others suggest that the hippocampus might mediate recollective and/or associative aspects of recognition memory, whereas the perirhinal cortex may mediate item memory. Here we investigate an alternative functional demarcation between these structures, following reports of stimulus-specific perceptual deficits in amnesics with medial temporal lobe (MTL) lesions. Using a novel recognition memory test for faces and scenes, participants with broad damage to MTL structures, which included the hippocampus and the perirhinal cortex, were impaired on both face and scene memory. By contrast, participants with damage limited to the hippocampus showed deficits only in memory for scenes. These findings imply that although both the hippocampus and surrounding cortex contribute to recognition memory, their respective roles can be distinguished according to the type of material to be remembered. This interaction between lesion site and stimulus category may explain some of the inconsistencies present in the literature.

Keywords: Recognition memory; Spatial memory; Amnesia; Hippocampus; Perirhinal cortex; Medial temporal lobe

Impairments in recognition memory are widely believed to be a key feature of medial temporal lobe (MTL) amnesia. Whether the hippocampus and perirhinal cortex make different contributions to this type of memory, however, remains controversial. One prominent theory proposes that both structures form part of a unitary declarative memory system supporting conscious recall of past experiences, and therefore, both are essential for intact recognition memory (Squire, Stark, & Clark, 2004; Squire & Zola-Morgan, 1991). An alternative view predicts that a network involving perirhinal cortex may be sufficient to support familiarity-based recognition memory for single items, in the absence of the hippocampus (Aggleton & Brown, 1999; Brown & Aggleton, 2001; Holdstock, 2005). According to this view, tasks requiring contextual information about the learning episode are hippocampally dependent and consequently hippocampal damage will impair performance on such tests.

In support of the latter theory, studies in hippocampal patients have reported intact recognition memory for single items coupled with impaired recall and/or impaired recognition memory for (cross-modal) associations (Aggleton et al., 2005; Baddeley, Vargha-Khadem, & Mishkin, 2001; Barbeau et al., 2005; Bastin et al., 2004; Holdstock, Mayes, Gong, Roberts, & Kapur, 2005; Mayes, Holdstock, Isaac, Hunkin, & Roberts, 2002; Mayes et al., 2004; Turriziani, Fadda, Caltagirone, & Carlesimo, 2004; Vargha-Khadem et al., 1997). Conversely, Squire and colleagues consistently find impaired recall and recognition memory for both single items and associations in their focal hippocampal patients (Manns, Hopkins, Reed, Kitchener, & Squire, 2003; Manns & Squire, 1999; Stark, Bayley, & Squire, 2002; Stark & Squire, 2003; Wais, Wixted, Hopkins, & Squire, 2006). For example, Gold et al. (2006) report deficits in item and source memory for words in patients with damage limited to the hippocampus. In addition, use of a similar task in functional magnetic resonance imaging (fMRI) revealed activation of the hippocampus and perirhinal cortex in healthy participants.

An alternative view that may partially explain this controversy is that different regions within the MTL may be involved in the processing of different stimulus categories, with the hippocampus and perirhinal cortex playing a critical role in spatial and object processing, even when there is minimal demand for

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0028-3932/$ – see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2007.04.004

declarative memory. Much of the evidence in support of this view has come from investigations in rats and monkeys that have focused on object perception after perirhinal lesions (Buckley, Booth, Rolls, & Gaffan, 2001; Buckley & Gaffan, 2006; Bussey, Saksida, & Murray, 2002; Bussey, Saksida, & Murray, 2003; Eacott & Gaffan, 2005). For example, monkeys with perirhinal lesions were found to be impaired on concurrent object discriminations with a high, but not low, degree of 'feature ambiguity', a property of visual discrimination problems that emerges when discriminating between objects with a large number of features in common (Bussey et al., 2002). In contrast, monkeys with hippocampal lesions performed normally on such tasks (Saksida, Bussey, Buckmaster, & Murray, 2006), a pattern also true of human amnesics with selective hippocampal damage (Barense et al., 2005).

The findings from these experiments have been interpreted as support for a view of visual processing in which the perirhinal cortex functions as the apex of the ventral visual processing stream, with perirhinal cortex containing representations of complex conjunctions of stimulus features, whereas more caudal regions (e.g., V4, TEO) house the components from which these conjunctions are formed (Bussey & Saksida, 2005). Lee, Buckley et al., 2005, Lee, Levi, Davies, Hodges, & Graham (2007) have recently proposed a similar role for the hippocampus in the processing of complex spatial scenes or spatial configurations based on data using a four-choice odd-one-out paradigm adapted from animal studies (Buckley et al., 2001). Lee, Buckley et al. (2005) observed deficits in patients with focal hippocampal lesions in the perceptual discrimination of virtual reality scenes, but not faces. A second group of patients with broader MTL damage that included the hippocampus and perirhinal cortex were impaired on both face and scene conditions, confirming a role for human perirhinal cortex in the discrimination of faces (see Buckley, 2005, for a review of similar experiments in monkeys with perirhinal lesions). These deficits were limited to trials where stimuli were presented from different, but not same, viewpoints, suggesting that view-invariant but not view-specific representations were impaired in these patients. These studies, when considered alongside other investigations revealing double dissociations in the involvement of MTL structures in object and spatial processing (e.g., early gene imaging, Aggleton & Brown, 1999, 2005; lesion studies, Winters, Forwood, Cowell, Saksida, & Bussey, 2004, in rats), highlight a key difference between stimulus categories that may be particularly important for understanding human recognition memory.

Here we investigate whether the stimulus specific effects seen on perceptual tasks in amnesic patients extend into the memory domain, by testing patients with amnesia on a novel recognition memory test for faces and scenes (existing standardised tests do not allow direct comparison of performance on these two stimulus categories). We tested whether deficits in the memory domain are limited to tasks requiring view-invariant representations by incorporating same and different view conditions. We predicted that hippocampal patients would show normal recognition memory for faces, but not scenes, whereas individuals with broader MTL lesions involving perirhinal cortex would show poor recognition memory regardless of stimulus type.

1. Materials and methods

1.1. Participants

Six amnesic patients with focal brain lesions participated in this study. Structural magnetic resonance imaging (MRI) scans in five of the patients were evaluated (see Section 1.2), and on the basis of these evaluations, patients were categorised into the following two groups: (1) individuals with selective hippocampal damage (HC group, $n = 3$) and (2) participants with broader MTL damage, including perirhinal cortex, in addition to the hippocampus (MTL group, $n = 3$). Of the three patients included in the MTL group (age = 69.7 years; education = 10.3 years; one female, two males), two had been diagnosed with viral encephalitis and the third had experienced traumatic intracerebral bleeding. Of the three patients categorised in the hippocampal group (age = 48.7 years; education = 13 years; all female), one had a diagnosis of viral encephalitis, another had cerebral anoxia in the context of suspected encephalitis, and the third had carbon monoxide induced hypoxia. One patient from the HC group (referred to as HC5) did not wish to undergo further scanning. We were unable to retrieve her previous scan, but the radiological report indicated selective hippocampal damage and her performance on standard neuropsychological tests was indistinguishable from the other cases with selective hippocampal damage. Exclusion of this patient from the analyses did not significantly alter the experimental findings.

Since the two patient groups were not matched in terms of age ($p < 0.05$) or sex, for the experimental tests, two groups of 12 healthy controls were recruited to match the two patient groups in terms of age, education and sex: HC controls: age = 48.8 years; education = 14.7 years; all female; MTL controls: age = 69.0 years; education = 11.6 years; 4 females, 8 males (all $p > 0.19$).

All participants gave informed consent before undertaking the study. This investigation received ethical approval from the Cambridge and Southampton Health Authority Local Research Ethics Committees (UK).

1.2. Scan rating method

The MRI scans from the patients were assessed using (a) detailed rating of a number of temporal lobe brain regions, based on a rating scale that focused on MTL regions (Barense et al., 2005; Galton et al., 2001; Lee, Bussey et al., 2005) and (b) MRIcro (Rorden & Brett, 2000) to delineate which brain regions highlighted from the rating scale were damaged in the two groups. The results of these evaluations are shown in Table 1 and Fig. 1. One hippocampal patient was not included in either analysis for the reasons given above. A further patient, referred to as MTL2, was not included in the second analysis since an electronic version of his scan was not available. Exclusion of either, or both, of these patients did not significantly alter the experimental findings.

The visual rating method assesses a total of nine regions, including (1) *anterior hippocampus*, which was rated on the anterior-most pontine slice and based on the widths of the choroid fissure and temporal horn and the height of the hippocampal formation; (2) *anterior temporal lobe*, which was based on the cerebral spinal fluid space between the back of the orbit and temporal pole; (3) *amygdala*, which was rated on the scan-slice anterior to the tip of the temporal horn; (4) *lateral temporal lobe*, which was rated on the same slice as the anterior hippocampus and was based on the cortical thickness of the superior and middle temporal gyri; (5) *posterior hippocampus*, which was rated on the anterior-most slice through the cerebral aqueduct in parallel with the anterior measure and according to the width of the temporal horn and the height of the hippocampal formation; finally (6) *anterior parahippocampal gyrus*; (7) *medial bank of the collateral sulcus*; (8) *lateral bank of the collateral sulcus*; (9) *occipitotemporal suclus*, which were all rated on the slice showing the collateral sulcus at its longest. Other than the anterior hippocampus, which was rated on a five point scale (normal = 0, severe atrophy = 4) based on Scheltens et al. (1992), all regions were assessed using a four point scale (normal = 0, severe atrophy = 3), with ratings for each area averaged across both hemispheres.

Table 1 displays the ratings for each individual patient and the mean scores for each of the three subject groups (HC, MTL and control). A repeated measures ANOVA with a within-group factor of 'region' and a between-group factor of 'subject group' revealed a significant difference in scores across the nine brain areas rated (Greenhouse-Geisser corrected $F_{(3.6, 50.7)} = 4.78$, $p < 0.01$).