



# A comparison of egocentric and allocentric spatial memory in a patient with selective hippocampal damage

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## Abstract

The spatial memory of a single patient (YR) was investigated. This patient, who had relatively selective bilateral hippocampal damage, showed the pattern of impaired recall but preserved item recognition on standardised memory tests that has been suggested by Aggleton and Shaw [Aggleton JP, Shaw C. Amnesia and recognition memory: a reanalysis of psychometric data. *Neuropsychologia* 1996;34:51–62] to be a consequence of Papez circuit lesions. YR was tested on three recall tests and one recognition test for visuospatial information. The initial recall test assessed visuospatial memory over very short unfilled delays and YR was not significantly impaired. This test was then modified to test recall of allocentric and egocentric spatial information separately after filled delays of between 5 and 60 s. YR was found to be more impaired at recalling allocentric than egocentric information after a 60 s interval with a tendency for the impairment to increase up to this delay. Recognition of allocentric spatial information was also assessed after delays of 5 and 60 s. YR was impaired after the 60 s delay. The results suggest that the human hippocampus has a greater involvement in allocentric than egocentric spatial memory, and that this most likely concerns the consolidation of allocentric information into long-term memory rather than the initial encoding of allocentric spatial information. The findings also suggest that YR's item recognition/free recall deficit pattern reflects a problem retrieving or storing certain kinds of associative information. © 2000 Published by Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

Patients with medial temporal lobe damage suffer anterograde amnesia which includes impairments of spatial memory [8,10,24,27,31,39,58,68–70,74]. Animal studies indicate that within this region the most critical structure for spatial memory is the hippocampus. Indeed, one of the major theoretical models of the role of the hippocampus in animals is the cognitive mapping theory [50,55]. This theory largely arose

from single cell recording studies in rats that identified 'place cells' [49,53]. These cells respond when the animal is in a particular place within an environment and, in some cases, they are insensitive to the direction in which the animal is facing. The cognitive mapping theory proposes that the hippocampus is critical for forming a representation of a place in the environment when this is identified by the relative position of an array of external stimuli or landmarks (i.e., using an allocentric frame of reference), but not when a location is identified by its relative position to the observer (i.e., using an egocentric frame of reference).

Subsequent single cell recording studies in rats have confirmed the presence of place cells in the hippo-

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campus [45,50,51,55] and evidence from lesions of the hippocampus [26,43] and fornix [52] of rats has provided further support for the cognitive mapping theory. The maintenance of place cell firing following removal of cues which define the environment has emphasised the mnemonic role of the rat hippocampus in processing allocentric spatial information [55]. In contrast to the rat studies, place cells have rarely been identified in monkeys as few studies have made recordings while the monkey has been moving freely within the environment. One such study [56] did identify place cells in the monkey hippocampus. However, a similar study which used a less complex environment and involved passive movement of the monkey failed to find such cells [64]. Instead cells were found within the hippocampus that responded to views and one cell which responded to a combination of view and place. Similar cells were identified in an earlier study [14] in which the monkey viewed stimuli presented in different positions on a screen. In that study the majority of these view cells were reported to code in allocentric coordinates. A further study of monkeys identified cells within the hippocampus whose response was dependent on the direction of auditory and visual stimuli [71]. Some of these cells were found to code in allocentric coordinates but others coded in egocentric coordinates. The evidence from monkey studies that the hippocampus plays a critical role in allocentric but not egocentric spatial memory is, therefore, less clear-cut than that from rat studies.

It is clearly of theoretical importance to determine the role of the human hippocampus in allocentric and egocentric spatial memory. Within the human spatial memory literature there have been relatively few attempts to develop spatial memory tests which emphasise the use of either an allocentric or an egocentric spatial frame of reference. Support for the role of the human hippocampus in allocentric spatial memory has come from a small number of studies which have found deficits in this aspect of memory following unilateral temporal lobectomy or unilateral hippocampal sclerosis [18,34] particularly on the right [1,13,44]. Further, one of these studies [18] suggested that right and left unilateral temporal lobectomy, in which the anterior 5.5–6.5 cm of the temporal lobe was removed, did not impair egocentric spatial memory. Consistent with these behavioural results, three positron emission tomography (PET) studies have shown activation of the right hippocampus whilst learning to navigate and orient oneself in an environment (topographical learning) [33,35,36], a task which is thought to rely on allocentric spatial memory. These studies, therefore, support a role for the human hippocampus in allocentric spatial memory. However, because the majority of studies have not used an appropriate egocentric comparison task, the

studies provide limited evidence as to whether the human hippocampus also plays an equivalent role in egocentric spatial memory.

The present study was designed to obtain measures of allocentric and egocentric spatial memory. Spatial recall was tested by requiring the subject to view a single light on a uniform board and then mark the position of the light, following a delay, after it had disappeared. Initially, memory was tested in a condition which allowed the use of both allocentric and egocentric frames of reference after short unfilled delays ('short delay' condition) in order to assess whether spatial information could be successfully encoded. The task was then modified to strongly encourage subjects to use an allocentric spatial reference frame to encode position. The subject viewed the light from one position around the board and then moved to another position before indicating its location. This manipulation, in which the relationship between the observer and environmental cues is changed but the relationship between these cues and the target location is maintained, is based on the manipulations which have been used to assess allocentric spatial memory in animal studies employing the '+' maze [51,55] and the Morris water maze [29,43,65]. Our manipulation is effectively the same as that used by Goldstein et al. [18] and by Abrahams et al. [1] to assess allocentric spatial memory in unilateral temporal lobectomy and hippocampal sclerosis patients. The task was also modified, in a novel way, to strongly encourage subjects to use egocentric spatial memory. In this condition the subject viewed the target light and indicated its location in the dark, a situation in which allocentric cues were eliminated. These allocentric and egocentric conditions used longer filled delays. Finally, a version of the allocentric task was developed to assess yes/no recognition memory.

The present case study reports the results of an individual (YR) who, consistent with [2], showed impaired recall but intact item recognition on standardised memory tests following bilateral damage to the hippocampus. YR was tested on the battery of spatial memory tests described above to compare her allocentric and egocentric spatial memory. The allocentric spatial recognition condition was included to test two possible explanations for YR's pattern of impaired recall but normal item recognition on standardised tests. One possible explanation is that there is an impairment in the processes which underlie recall but which are not involved in recognition. If this explanation is correct YR would be unimpaired on the recognition version of the allocentric condition and on any recognition task. The second explanation is that recall and item recognition differ in the type of information which is retrieved and it is possible that recall depends to a much greater extent than

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