

## Role of the hippocampus in imagination and future thinking

Squire et al. (1) recently asserted that patients with bilateral hippocampal damage can imagine future experiences. This contradicts a number of previous reports where amnesia and bilateral hippocampal lesions have been found to cause significant impairment in imagining fictitious and future scenarios (2–4). Based on their findings, Squire et al. (1) concluded that the capacity for imagining the future is independent of the hippocampus. However, there are several aspects of their study that make this conclusion uncertain.

A striking feature of the patients of Squire et al. (1) was their apparent lack of impairment—they could recall events from the remote past, were able to recall recent events, and could imagine future scenarios. Despite the absence of statistically significant findings, the paper by Squire et al. (1) repeatedly stated that the patients were impaired at recalling recent autobiographical events, but their own statistics showed that this was not the case [ $t(11) = 1.9, P = 0.08$ ; p. 19044 in ref. 1]. Given that patients with impaired imagination and future thinking typically have co-occurring anterograde amnesia for autobiographical events (2–4), which was not true here, makes the patients of Squire et al. (1) distinct from the other reported cases.

Although Squire et al. (1) used some aspects of a previous scoring system to examine event descriptions (3), the most crucial measure, the spatial coherence index, was omitted. This index assesses the contiguousness and spatial integrity of an imagined experience. A lack of spatial coherence was found to underpin the performance deficit of patients in a previous study of imagination and future thinking (3). Interestingly, the number of spatial references made by both controls and patients in the study by Squire et al. (1) was far less than controls in other studies using this scoring protocol (3, 5). This strongly suggests that participants did not have vivid and coherent scenarios in mind but may, instead, have supplied descriptions that were more semantic in nature, and recall from semantic memory is spared in patients with damage to the hippocampus. This semantic bias is likely caused by the single word cues used by

Squire et al. (1) compared with the full sentence descriptors used in other studies (3, 5), which specifically encourage rich visualization.

Squire et al. (1) concluded that deficits in imagining the future reported by Hassabis et al. (3) were caused by the specific etiology of their patients (limbic encephalitis) causing more extensive damage and impairments than just to the hippocampus and memory. However, the patients of Hassabis et al. (3) were tested long after their acute illness, had normal neuropsychological profiles at the time of testing (excepting memory), and were specifically selected for their circumscribed hippocampal lesions. Moreover, the fact that other independent studies<sup>\*,†</sup> with a range of etiologies have since replicated the results of Hassabis et al. (3) renders the limbic encephalitis notion untenable.

In conclusion, a number of independent studies have shown that bilateral hippocampal damage and amnesia impair the ability to imagine fictitious and future events. Specific features of the participants and methods in the study by Squire et al. (1) likely contributed to their anomalous result.

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