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Imagining fictitious and future experiences: Evidence from developmental amnesia

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ABSTRACT

Patients with bilateral hippocampal damage acquired in adulthood who are amnesic for past events have also been reported to be impaired at imagining fictitious and future experiences. One such patient, P01, however, was found to be unimpaired on these tasks despite dense amnesia and 50% volume loss in both hippocampi. P01 might be an atypical case, and in order to investigate this we identified another patient with a similar neuropsychological profile. Jon is a well-characterised patient with developmental amnesia and 50% volume loss in his hippocampi. Interestingly both Jon and P01 retain some recognition memory ability, and show activation of residual hippocampal tissue during fMRI. Jon's ability to construct fictitious and future scenarios was compared with the adult-acquired cases previously reported on this task and control participants. In contrast to the adult-acquired cases, but similar to P01, Jon was able to richly imagine both fictitious and future experiences in a comparable manner to control participants. Moreover, his constructions were spatially coherent. We speculate that the hippocampal activation during fMRI noted previously in P01 and Jon might indicate some residual hippocampal function which is sufficient to support their preserved ability to imagine fictitious and future scenarios.

1. Introduction

The hippocampus is part of a network of brain regions acknowledged to play a role in retrieving autobiographical memories (Cabeza & St Jacques, 2007; Maguire, 2001; Spreng, Mar, & Kim, 2009; Svoboda, McKinnon, & Levine, 2006) and supporting spatial navigation (Bird & Burgess, 2008; Burgess, Maguire, & O'Keefe, 2002). In the last few years, functional MRI (fMRI) findings have indicated the hippocampus is also involved in imagining fictitious episodes (Hassabis, Kumaran, & Maguire, 2007; Summerfield, Hassabis, & Maguire, 2009, 2010), and the simulation of plausible personal future events (e.g. Addis & Schacter, 2008; Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis, Wong, & Schacter, 2007; Botzung, Denkova, & Manning, 2008; Okuda et al., 2003; Szpunar, Watson, & McDermott, 2007). Further compelling evidence for this comes from patients with damage thought to be relatively restricted to the hippocampus bilaterally. Hassabis, Kumaran, Vann, and Maguire (2007; see also Klein, Loftus, & Kihlstrom, 2002; Rosenbaum et al., 2005) tested five patients with such damage that was acquired in adulthood, rendering them amnesic. They were asked to imagine and describe fictitious scenarios and also possible plausible future episodes. The patient group was significantly impaired relative to control participants on both tasks, and a possible source for their deficit was identified. Whilst patients were able to produce relevant details when asked to imagine, their descriptions lacked spatial coherence and were fragmented. It was concluded that the hippocampus may play a critical role in imagination by binding together the disparate elements of an event or scene (Cohen & Eichenbaum, 1993; Hassabis, Kumaran, Vann, et al., 2007; O'Keefe & Nadel, 1978).

The involvement of the hippocampus (and other brain areas) in supporting apparently disparate functions such as autobiographical memory, spatial navigation, imagination, and future thinking, led Hassabis and Maguire (2007, 2009) to propose that they were underpinned by a common set of processes which they described as 'scene construction'. This involves the mental generation and maintenance of a complex and coherent scene or event. This is achieved by the reactivation, retrieval and integration of relevant semantic, contextual and sensory components, stored in their modality specific cortical areas (Wheeler, Petersen, & Buckner, 2000), the product of which has a coherent spatial context (Hassabis, Kumaran, Vann, et al., 2007), and can then later be manipulated and visualised.

Whilst the findings of Hassabis, Kumaran, Vann, et al. (2007) of deficient performance on the imagination task following hip-

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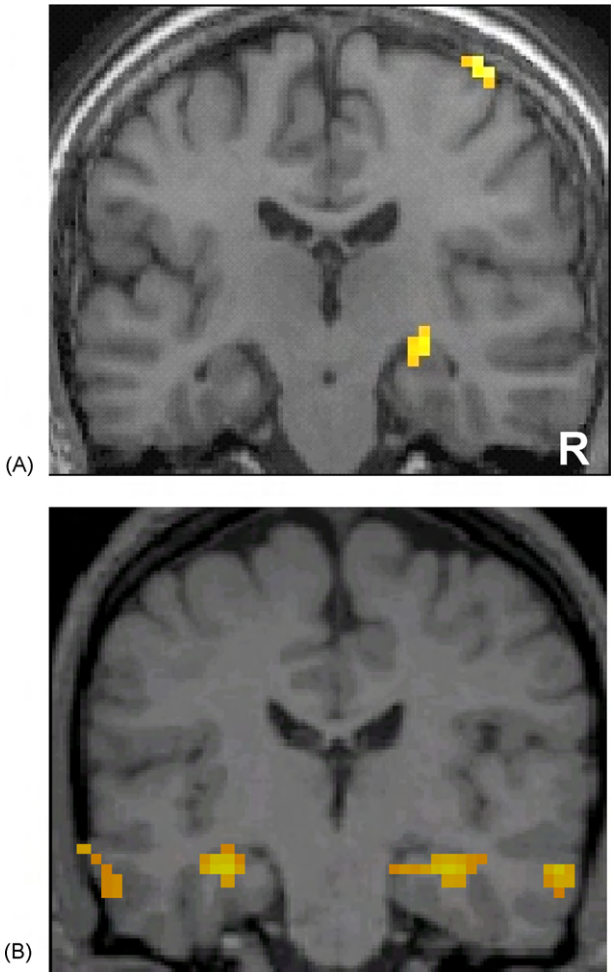

Fig. 1. FMRI data from adult-acquired case P01 and developmental amnesia patient Jon. Both data sets were acquired on the same 1.5 T MRI scanner. (A) P01's right hippocampus was active during the incidental acquisition of facts (data from Hassabis, Kumaran, Vann, et al., 2007 – Supplementary Material). (B) Jon's hippocampi were active during an autobiographical memory recall task (data from Maguire et al., 2001).

pocampal pathology are supportive of the concept of scene construction, it is notable that one of the five patients in that study was unimpaired. P01 (Hassabis, Kumaran, Vann, et al., 2007; also known as KN – Aggleton et al., 2005; McKenna & Gerhand, 2002), despite being profoundly amnesic for past experiences, was able to achieve rich scene construction with clear spatial coherence that was at the top end of the range of control participants. P01's pathology was acquired in adulthood, leaving him with almost 50% volume loss in both hippocampi (Aggleton et al., 2005). He was also very impaired on tests of recall, both for anterograde episodic memory and retrograde memory for autobiographical events, for which he had virtually no reliable recollections (Hassabis, Kumaran, Vann, et al., 2007). Despite this, his IQ was in the high average range, and he performed within normal limits on a number of tests of recognition (Aggleton et al., 2005). He also retained some ability to acquire new semantic information (McKenna & Gerhand, 2002). FMRI scanning revealed that there was residual BOLD activity in his right hippocampus during the incidental (and successful) acquisition of facts (Fig. 1a; see Hassabis, Kumaran, Vann, et al., 2007 – Supplementary Material; see also Maguire & Frith, 2004). Hassabis, Kumaran, Vann, et al. (2007) speculated that P01 may have retained a limited degree of residual hippocampal functionality that supported his performance on the imagination task.

P01 is just one patient who has preserved scene construction ability, and it is possible that he is atypical, making his relevance for understanding hippocampal function and the imagination of future scenarios uncertain. In order to understand more about the circumstances in which the ability to imagine fictitious and future scenarios might be preserved in the context of hippocampal damage, in the first instance it would be informative to identify other patients who perform similarly to P01 on such tasks. We noted that P01 has several features in common with another group of patients, namely those with developmental amnesia (DA). Patients with DA, a syndrome caused by relatively selective damage to the hippocampus following hypoxic-ischaemic episodes sustained in childhood, are able to acquire normal levels of intelligence and general knowledge despite a severe impairment in remembering the events of daily life (Vargha-Khadem et al., 1997). This dissociation between semantic and episodic memory (Tulving, 1972), seems to be accompanied by a second dissociation, between relatively preserved recognition ability and a marked impairment in recall (Adlam, Malloy, Mishkin, & Vargha-Khadem, 2009; Baddeley, Vargha-Khadem, & Mishkin, 2001; Mishkin, Suzuki, Gadian, & Vargha-Khadem, 1997; Vargha-Khadem et al., 1997). One particularly well-characterised patient with DA is Jon (see case summary below, and e.g. Adlam et al., 2009; Baddeley et al., 2001; Brandt, Gardiner, Vargha-Khadem, Baddeley, & Mishkin, 2008; de Haan, Mishkin, Baldeweg, & Vargha-Khadem, 2006; Gadian et al., 2000; Gardiner, Brandt, Vargha-Khadem, Baddeley, & Mishkin, 2006; Hartley et al., 2007; Mishkin et al., 1997; Vargha-Khadem et al., 1997). As well as the primary features of DA noted above, like P01 with adult-acquired pathology, Jon has ~50% bilateral hippocampal volume loss in the face of a high average IQ. Interestingly, Jon appears to have preserved recollection of a small set of autobiographical events, that when recalled during fMRI were associated with bilateral activation of his residual hippocampal tissue (Maguire, Vargha-Khadem, & Mishkin, 2001; see Fig. 1b).

Given the similarity in profiles between developmental case Jon and adult-acquired case P01, we wondered how Jon would fare in constructing imagined scenarios. The commonalities between both cases led us to hypothesise that Jon too might be unimpaired. In order to examine this, we administered exactly the same tests of imagining fictitious and future scenarios to Jon as those undertaken by P01 and the other adult-acquired cases of hippocampal pathology described by Hassabis, Kumaran, Vann, et al. (2007).

2. Methods

2.1. Case description

Jon, who was 28 years old at time of testing, is a well-documented case of developmental amnesia (see above). Briefly, he was born prematurely at 26 weeks of gestation. He weighed less than 1 kg, suffered breathing problems and during his first 6 weeks of life required intubation and positive pressure ventilation for severe apnea (Gadian et al., 2000). He subsequently showed steady improvement and normal development, but by the age of five, memory problems were noted, and have since continued to be prominent. Direct measurement of Jon's MRI scans in adulthood indicated a reduction of ~50% in the volume of both left and right hippocampal regions, with no evident pathology in the rest of the medial temporal lobe (Gadian et al., 2000; Vargha-Khadem et al., 1997). Consistent with his hippocampal abnormality, Jon has difficulty in reliably finding his way. He also tends to forget where belongings are normally kept, has problems remembering everyday events such as TV programmes just seen and is typically unable to give a detailed account of his activities earlier in the day.

On the other hand, he has a full scale IQ of 114 (high average), and performs normally on tests of reading, syntax, semantics and vocabulary (see Baddeley et al., 2001). He was able to attend normal school and acquire and retain the necessary semantic information that this involves. However, he performs poorly on a range of standardized memory tests, particularly when these involve recall rather than recognition. His performance on measures of recognition is relatively well preserved; he performs at a comparable level to control participants on a number of tests (Baddeley et al., 2001), or at a slightly lower level on others (Gardiner et al., 2006).