

Qualities of Autobiographical Memory Modulate Hippocampal Activation During Retrieval: Preliminary Findings of an fMRI Study

Addis, D. R.^{1,2}, Moscovitch, M.^{2,3}, Crawley, A. P.^{1,4}, & McAndrews, M. P.^{1,2}

¹ Toronto Western Research Institute, University Health Network, Toronto, Ontario, Canada

² Department of Psychology, University of Toronto, Toronto, Ontario, Canada

³ Rotman Research Institute, Baycrest Centre for Geriatric Care, Toronto, Ontario, Canada

⁴ Department of Medical Imaging, University of Toronto, Toronto, Ontario, Canada

Autobiographical memory (AM) retrieval appears to specifically activate the hippocampus. It is likely that qualities of AMs that contribute to re-experiencing, such as detail, emotionality and personal significance, modulate hippocampal activation. We conducted an event-related fMRI study, in which participants retrieved 40 AMs, and rated each for either level of detail, emotion or personal significance. Two control tasks (sentence completion and size discrimination) were also included. Retrieval of AMs activated a previously reported, predominantly left-lateralized memory network. Retrieval of AMs rated high in detail, emotionality or personal significance resulted in greater hippocampal activation than AMs low in these qualities. Other brain regions showed differential engagement depending on the quality rated, suggesting the activation of different networks of which the hippocampus is a key structure.

It is well established that the medial temporal lobe is important in the retrieval of episodic memory. Recent neuroimaging studies have reported the activation of a predominantly left-lateralized memory network during memory retrieval (Maguire, Vharga-Khadem & Mishkin, 2001). This network includes medial temporal structures, such as the hippocampus and parahippocampal gyrus, in addition to the medial prefrontal cortex, temporal pole, thalamus, posterior cingulate, retrosplenial cortex and the temporoparietal junction. Consistent with lesion evidence, it appears that medial temporal structures play a critical role in this memory network, particularly in the retrieval of certain types of episodic memory, namely autobiographical memory (AM). For example, Maguire et al. (2001) report that retrieval of autobiographical events activated the left hippocampus. Ryan et al. (2001) found that both recent and remote AMs activated the hippocampus bilaterally.

It is still not clear, however, why the hippocampus is preferentially activated by the retrieval of AMs. While this could be related to the personal nature and temporal specificity of AMs, there is evidence to suggest that hippocampal activation is modulated by the retrieval of certain AMs requiring integration of rich detail and a re-experiencing of the event. Maguire and colleagues (2001) investigated the neural correlates of AM retrieval in a patient who, because of hippocampal damage, distinguished between AMs which he remembered and those which he only knew about. The retrieval of remembered AMs resulted in greater activation of the hippocampus bilaterally than known events, suggesting that hippocampal activation is related to the re-experiencing of AMs. Thus, qualities that contribute to re-experiencing, such as detail, emotionality and personal significance, may be particularly relevant. As yet, however, the modulating effect of these qualities on the hippocampal activation evident during AM retrieval has not been investigated directly.

Accordingly, we conducted an event-related fMRI study to investigate whether level of detail, emotionality and personal significance modulates hippocampal activation during AM retrieval. We predicted that firstly, we would see activation of a left-lateralized memory network during AM retrieval, and secondly, that AMs high in detail, emotionality and personal significance would result in a greater level of hippocampal activation relative to memories low in these qualities.

Methods

Twelve healthy adults (6 male, 6 female, age range, 20 to 40 years) with no history of neurological or psychiatric impairment, participated in this study. At least 48

hours prior to scanning, each participant completed a 2-hour pre-scan interview, in which they produced 40 AMs. A list of cues (e.g., “an accident”) was provided to facilitate retrieval, but event memories did not have to be limited to these cues. Participants provided a very brief “title” for each AM, to be later used as a cue during scanning. Each AM was also rated on a five-point scale for the level of detail, emotionality (i.e., the level of emotion the memory currently evokes for the participant), and personal significance (i.e., how life-changing or self-defining the event is).

Immediately prior to scanning, the AM titles produced in the pre-scan interview were repeated to the participant. This was done to avoid any confusion during scanning that could potentially arise from using very brief memory titles. Participants were also presented with the five-point rating scales they would be using in the scanner.

Participants completed two functional scans in a single session. During each scan, 20 of the AMs given in the pre-scan interview were presented. Each AM title was presented visually for six seconds, and participants had been instructed to retrieve the relevant memory. They were then presented with a five-point rating scale (either level of detail, emotionality or personal significance) for four seconds. During this time, they rated the memory by lifting the corresponding finger of the right hand (thumb=1, etc.), which was recorded by a researcher present in the scanning room. The rating scale remained the same over the duration of a scan, but differed between the two scans. This was followed by a rest period of six seconds; participants had been instructed to focus on resting.

Two control tasks were randomly interspersed between the AM tasks. Ten sentence completion tasks were included in each scan (Ryan et al., 2001), which

consisted of a sentence missing the last word (e.g., “The dog ate a _____”). Participants were instructed to silently complete each sentence with a word. The inclusion of this task was to provide a control that involved the retrieval of information from semantic rather than AM. To provide a similar control for visuospatial information, 10 size discrimination tasks were included in each scan. Participants were required to judge the larger of two items. Thus, the names of two objects were presented (e.g., “CD or coin”) along with the word “Biggest” to remind participants of the judgement required. Each control task was presented for four seconds. This was followed by the four-second presentation of a five-point rating scale for difficulty of task completion, included as a control for the rating made in the memory task. Participants then rested for eight seconds.

Functional data were acquired on a 1.5 Tesla Signal MR System (GE Medical Systems, Milwaukee WI), using single-shot spiral acquisition (TE = 40 ms, TR = 2,000 ms, FOV = 220 mm). Slices were 5 mm thick, with a 1 mm gap, covering the entire brain. These were acquired in a coronal-oblique orientation, with each slice being perpendicular to the long axis of the hippocampus. Preliminary event-related, fixed-effects analyses were conducted using AFNI software. Four comparisons were made: (1) AMs versus the two control tasks; (2) high detail versus low detail AMs; (3) high emotion versus low emotion AMs; and (4) high personal significance versus low personal significance AMs. The last three contrasts included only those AMs given the highest and lowest in-scanner ratings by a subject on the relevant dimension.

Results

The comparison of AM retrieval with the two control tasks, sentence completion and size discrimination, revealed the activation of a predominantly left-lateralized memory network. This network included the medial prefrontal cortex, hippocampus, parahippocampal gyrus, thalamus, posterior cingulate, retrosplenial cortex and precuneus. The comparisons of AMs high and low in different qualities revealed a modulation of hippocampal activation. The retrieval of AMs rated high in detail resulted in greater activation of the left posterior hippocampus and parahippocampal gyrus. Retrieval of AMs high in emotion was associated with increased activation of the left hippocampus and the anterior cingulate. Finally, the retrieval of AMs high in personal significance resulted in greater activation of the hippocampus bilaterally, the left thalamus and the precuneus.

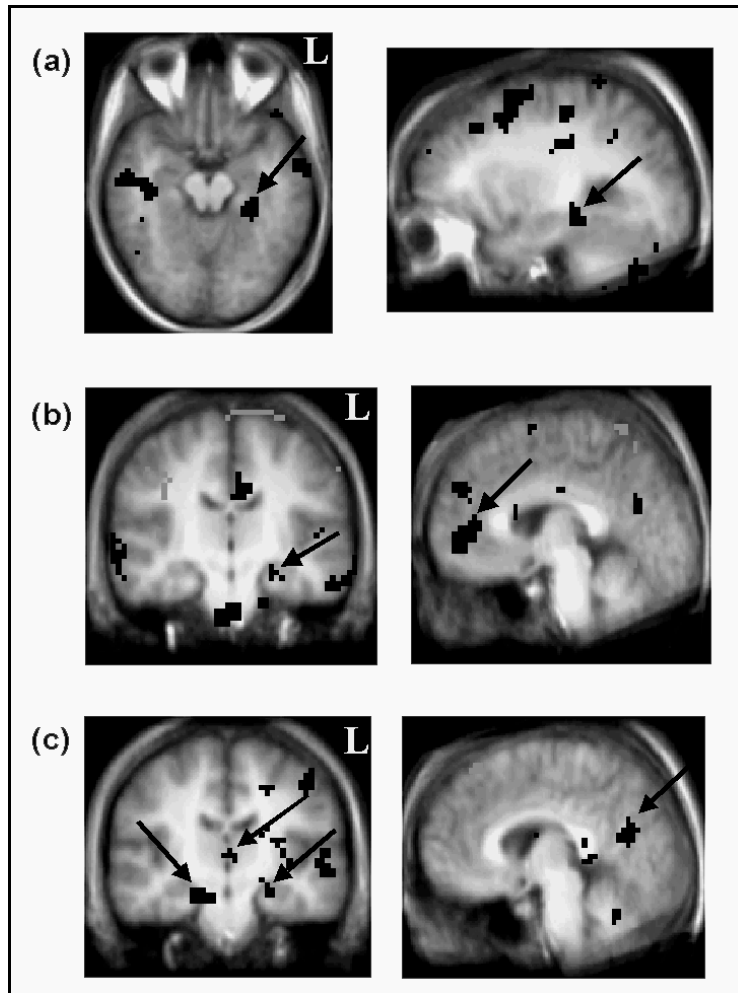


Figure 1. Activations showing modulation by AM qualities: (a) detail; (b) emotionality; and, (c) personal significance. In each case, increased activity was seen for retrieval of AMs high in these qualities. Arrows indicate activations of interest, including hippocampus (a, b, c), anterior cingulate (b), thalamus and precuneus (c).

Discussion

We replicated the finding of the activation of a predominantly left-lateralized memory network during the retrieval of AMs documented in previous studies (Maguire et al., 2001). The major preliminary finding of this study, however, is that the activation of

the hippocampus during AM retrieval appears to be modulated by the level of particular qualities contributing to the re-experiencing of AMs. Thus, we confirmed our hypothesis that the retrieval of AMs high in detail, emotionality and personal significance activates the hippocampus to a greater extent than AMs low in these qualities. This is consistent with the idea that the hippocampus integrates the various aspects of an AM during retrieval. Thus, if a particular AM requires the integration of a greater level of detail, emotion, and personal significant qualities upon retrieval, the level of hippocampal involvement may be increased accordingly.

It is notable that the nature of hippocampal activations differs in terms of extent of lateralization and the location of activation along the axis of the hippocampus, depending on the quality rated. Specifically, retrieval of greater detail was associated with left posterior hippocampal activation, compared with the more anterior activations associated with retrieving AMs high in emotion (left hippocampus) and personal significance (bilateral hippocampus). This suggests that different regions of the hippocampus may have specific roles in the integration and retrieval of different aspects of autobiographical memories.

An unexpected, but interesting finding is that other brain regions showed differential engagement depending on the particular quality rated. This suggests that, depending on the qualities of an AM, retrieval may require the activation of different networks, of which the hippocampus is always a key structure. When retrieving AMs high in detail, the left parahippocampal gyrus is also activated, consistent with evidence that this region plays a role in retrieving the contextual details of AMs (Burgess, Maguire, Spiers, & O'Keefe, 2001). The retrieval of AMs rated high in emotion also

activated the anterior cingulate, a region of known importance in emotional processing (Whalen et al., 1998). The retrieval of AMs high in personal significance also activated the left thalamus and notably, the precuneus. This suggests that this region, known to be active during episodic memory retrieval (Cabeza, Dolcos, Prince, Rice, Weissman & Nyberg, 2003), may play a role in the retrieval of information regarding personal significance. Further analyses using functional and effective connectivity will enable confirmation and clarification of these different AM retrieval networks.

References

Burgess, N., Maguire, E. A., Spiers, H. J., & O'Keefe, J. (2001). A temporoparietal and prefrontal network for retrieving the spatial context of lifelike events. *Neuroimage*, *14*, 439-453.

Cabeza, R., Dolcos, F., Prince, S. E., Rice, H. J., Weissman, D. H., & Nyberg, L. (2003). Attention-related activity during episodic memory retrieval: a cross-function fMRI study. *Neuropsychologia*, *41*, 390-399.

Maguire, E. A., Varga-Khadem, F., & Mishkin, M. (2001). The effects of bilateral hippocampal damage on fMRI regional activations and interactions during memory retrieval. *Brain*, *124*, 1156-1170.

Ryan, L., Nadel, L., Keil, K., Putnam, K., Schnyer, D., Trouard, T., & Moscovitch, M. (2001). Hippocampal complex and retrieval of recent and very remote autobiographical

memories: Evidence from functional magnetic resonance imaging in neurologically intact people. *Hippocampus*, *11*, 707-714.

Whalen, P. J., Bush, G., McNally, R. J., Wilhelm, S., McInerney, S. C., Jenike, M. A., & Rauch, S. L. (1998). The emotional counting stroop paradigm: A functional magnetic resonance imaging probe of the anterior cingulate affective division. *Biological Psychiatry*, *44*, 1219-1228.