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Emotional memory: Separating content and context

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Abstract

It is now well established that emotion enhances episodic memory. However, it remains unclear whether the same neural processes underlie enhancement of memory for both emotional stimuli and neutral stimuli encoded in an emotive context. We designed an experiment that specifically attempted to separate these effects and that was validated on 30 participants. We then used functional magnetic resonance imaging (fMRI) to examine the neural correlates of encoding and retrieval of the two classes of stimuli in 12 healthy male volunteers. We predicted that aversive emotional context would enhance memory regardless of content and that activation of anterior cingulate would be inversely related to retrieval of aversive items. Both predictions were supported. Furthermore we demonstrated apparent asymmetrical lateralisation of activation in the hippocampal/parahippocampal complex during recognition of words from aversive sentences: more left-sided activation for neutral words from aversive contexts, and more right-sided activation for aversive content words. These findings, if applicable to the wider population, may have application in a range of psychiatric disorders where interactions between emotion and cognition are relevant.

Keywords: Emotion; Memory; Amygdala; Hippocampus; Anterior cingulate cortex; Functional MRI

1. Introduction

Interactions between emotion and memory play an important role in psychiatry. For example, cognitive theories of depression emphasize the role of negatively valenced assessments of the past, while post-traumatic stress disorder (PTSD) arises as a consequence of an aversive event and the handling of that event by memory and other cognitive systems. While there is strong evidence that memory is enhanced by emotional arousal at the time of encoding (Burke et al., 1992; Sierra and Berrios, 1999), the specific neural and cognitive mechanisms remain elusive. Animal research (Gallagher and Chiba, 1996; LeDoux, 1998) has implicated the amygdaloid com-

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plex (AC) in the formation of conditioned fear responses, leading to the idea that this structure may be involved in the formation of emotional memories in man.

There is now good evidence for amygdala involvement in human emotional memory. Patients with amygdala lesions have deficits in recognizing the emotions of others (Adolphs et al., 1994; Broks et al., 1998), and may also lose the enhancement of memory normally conferred by emotion (Phelps and Anderson, 1997). A study examining the memory of people with Alzheimer's disease for an emotional event (a devastating earthquake in Kobe, Japan) found that impairment of memory for this event was correlated with the density of amygdala damage (Mori et al., 1999). A landmark PET study (Cahill et al., 1996) in which subjects viewed emotionally arousing video clips found that amygdala activation at encoding was correlated with subsequent recall of the emotional material, suggesting that amygdala arousal may modulate the formation of memories for emotional material. This idea is supported by studies using pharmacological manipulation to influence arousal (McGaugh et al., 1996; O'Carroll et al., 1999), and by an event-related fMRI study (Canli et al., 2000) in which, within individual subjects, amygdala activation at encoding was found to correlate with intensity of emotional response to stimuli. With regard to a possible role for the amygdala in retrieval, animal studies suggest that an intact amygdala is required for encoding (McGaugh et al., 1996), but not recall, of emotional material, although elsewhere (Dolan et al., 2000) it has been suggested that the left amygdala may have a specific role in retrieval of emotional memories. A more recent study (Dolcos et al., 2004) supports the idea that interactions between the amygdala and the medial temporal lobe (MTL) memory system underlie the emotional enhancement of memory, and suggests that more anterior parts of the MTL have a specific role in encoding emotional information.

In considering emotional memory, relative contributions of, firstly, emotional material (content) and, secondly, the context in which this material occurs are of particular relevance in understanding the role of emotional memory in psychopathology. Studies of these effects have yielded conflicting results (Burke et al., 1992). After an emotional event, while recall of the event itself is enhanced, memory for surrounding contextual information is variously found to be either enhanced or diminished, raising the possibility that memory for content and context are subserved by different neural networks. Indeed, work by Kensinger et al. (2002) showed that the direct enhancement effect on memory of emotional content is preserved in normal ageing while that of context is diminished. Patients with Alzheimer's disease, presumed to have diffuse brain disease, showed loss of emotional enhancement from both content and context.

A small number of functional imaging studies have attempted to address these issues. Maratos et al. (2001) examined memory for emotional context by testing recognition memory for neutral words presented in emotional sentences. However, there was no test of recall for words whose content was intrinsically emotive, and thus no comparison of the neural correlates of emotional content and context recognition memory. Erk et al. (2003) examined the effect of emotional context at encoding on subsequent memory performance, but scanning data were only obtained during encoding. One recent study (Smith et al., 2004) examined contextual influences on both encoding and recognition memory by the use of pictorial stimuli presented on either emotional or neutral backgrounds. However, this method of associating stimulus with context may not be analogous to real-life situations, where contextual information is likely to have more semantic relevance than an arbitrary association. In this study, we aimed to examine the neural correlates of memory for both content and context, encoded in such a way that they were semantically linked.

In addition to studying temporal lobe structures involved in emotion and memory, we wished to examine the role of anterior cingulate cortex (ACC) in encoding and subsequent recognition of emotional material. It has been suggested (Hamner et al., 1999) that the ACC interprets and contextualises emotional information, thus "rationalising" and dampening the emotional response, this being consistent with a study (Bremner et al., 1999) in which war veterans with post-traumatic stress disorder (PTSD) showed less ACC activation in response to combat-related stimuli than veterans without PTSD. Thus this area has particular significance for understanding the role of context in emotional memory.