



# Neural activity associated with episodic memory for emotional context

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Received 17 November 2000; received in revised form 31 January 2001; accepted 2 February 2001

## Abstract

To address the question of which brain regions subserved retrieval of emotionally-valenced memories, we used event-related fMRI to index neural activity during the incidental retrieval of emotional and non-emotional contextual information. At study, emotionally neutral words were presented in the context of sentences that were either negatively, neutrally or positively valenced. At test, fMRI data were obtained while participants discriminated between studied and unstudied words. Recognition of words presented in emotionally negative relative to emotionally neutral contexts was associated with enhanced activity in right dorsolateral prefrontal cortex, left amygdala and hippocampus, right lingual gyrus and posterior cingulate cortex. Recognition of words from positive relative to neutral contexts was associated with increased activity in bilateral prefrontal and orbitofrontal cortices, and left anterior temporal lobe. These findings suggest that neural activity mediating episodic retrieval of contextual information and its subsequent processing is modulated by emotion in at least two ways. First, there is enhancement of activity in networks supporting episodic retrieval of neutral information. Second, regions known to be activated when emotional information is encountered in the environment are also active when emotional information is retrieved from memory. © 2001 Elsevier Science Ltd. All rights reserved.

*Keywords:* Emotion; Episodic memory; fMRI; Negative; Positive; Neuroimaging

## 1. Introduction

A small number of functional neuroimaging studies have investigated the brain regions and circuits activated during explicit retrieval of emotionally toned items. In one of the first such studies it was reported that activity in occipital-parietal regions was enhanced during visualisation from memory of previously viewed negative images relative to neutral images [27]. The finding of enhanced activity in sensory regions during emotional memory retrieval was replicated by Taylor et al. [58], who found greater activity in the lingual gyrus (BA 18) during recognition of previously studied negative images, relative to neutral images, in the absence of the modulation of any other retrieval-related activity.

In a more recent study, Dolan et al. [11] reported that recognition memory for emotional relative to neutral pictures was associated with activation in the anterior temporal pole and the amygdala, leading these authors to conclude that emotional memory retrieval recruited brain regions specialised for processing the affective significance of stimuli.

The present investigation was concerned with characterising the brain activity associated with retrieval of emotionally toned contexts rather than retrieval of items with inherent emotional tone. To the best of our knowledge, only one earlier neuroimaging study [33] has investigated the neural correlates of retrieval of such contexts. The results of this electrophysiological study suggested that activity in the same network that supports episodic retrieval of neutral information is enhanced during retrieval of emotional information. Specifically, it was suggested that the incidental retrieval of emotional contextual information was associ-

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ated with enhanced activity in the same neural systems that support the conscious recollection and subsequent 'post-retrieval' processing of emotionally neutral information. In particular, it was suggested that such additional activity would be found in the medial temporal/posterior cortical regions subserving the initial retrieval of episodic information [37,49] and in right prefrontal regions supporting the subsequent monitoring and evaluation of the retrieved information (e.g. [48]).

The present study employed event-related fMRI to investigate the incidental retrieval of emotional and neutral contexts using a procedure similar to that employed by Phelps et al. [39] (see also [33]) which, unlike most prior studies of emotional memory, did not confound the emotional valence of the retrieval cues with the valence of the to-be-retrieved information. By contrasting the neural activity elicited by a single kind of test item (emotionally neutral words) as a function of the emotional valence of its study context, any difference in the activity elicited by test items belonging to different classes of context can be attributed unequivocally to their respective encoding contexts.

## 2. Method

The experimental procedures were approved by the joint Medical Ethics Committee of the National Hospital for Neurology and Neurosurgery and the Institute of Neurology.

### 2.1. Participants

Thirteen right-handed participants aged between 18 and 30 years were employed in the study after giving informed consent. One participant's data were rejected because of very poor behavioural performance. The 12 participants whose data were analysed consisted of seven females and five males. All reported good health and no history of neurological illness.

### 2.2. Experimental material

One hundred and twenty words normed for neutral emotional valence (see below) were used as critical stimuli. The words varied in length between four and ten letters and in frequency between 30 and 100 per million [14]. For each word one negative, one neutral, and one positive sentence were constructed. For example, for the critical word 'corn' the following sentences were generated as negative, neutral and positive sentences, respectively. 'The farmer was shredded when he fell into the corn grinder'; 'The farm labourers began harvesting the corn'; and 'The farmer was overjoyed with his bountiful crop of corn'. Critical words never

featured in sentences other than their designated neutral, negative or positive sentences.

### 2.3. Word norms and selection

Normative valence ratings were collected for 320 ostensibly neutral words. The words were randomly intermixed with 35 emotionally negative words and 35 emotionally positive words (taken from Siegle [53]). Ten participants were given the resulting list of 390 words and asked to rate each word on a Likert scale (ranging from  $-3$  to  $+3$ ) according to how emotionally 'negative', 'neutral' or 'positive' they felt it to be. The average ratings given to the negative, neutral and positive words were  $-1.8$ ,  $0.4$  and  $1.6$ , respectively. Of the 320 'neutral' words, 21 were dropped because they received ratings outside the range  $\pm 1$ , another 131 were dropped because of difficulties in constructing a negative, neutral or positive sentence, and 48 words were used as filler items. The remaining 120 words were used as critical stimuli.

### 2.4. Experimental lists

Eight study lists were created, each containing a set of 15 negative, 15 neutral and 15 positive sentences. The sentences in the study lists were randomly ordered and a neutral filler sentence was added to the beginning and end of each study list. Six test lists were created, each with a different randomised order, such that each study list could be followed by a test list containing the 45 old words from the sentences in the study block and 15 previously unseen words. Two filler words were added to the beginning of each test list.

To accommodate the two study-test sessions, study lists were paired such that across the whole experiment there were four study sets (each set containing a list for session 1 and corresponding list for session 2). Test lists were similarly paired, resulting in three test sets. Study and test sets were then combined resulting in 12 possible study-test set combinations, one for each participant.

Study and test lists were assigned to participants such that, across the experiment, each critical word appeared three times as a new item and three times each in a negative, neutral and positive sentence.

### 2.5. Procedure

Participants were given a description of the study task before entering the scanner. They were informed that the experiment would involve the presentation of emotional sentences and that parts of the experiment would involve a memory task. An example of the study phase was then given which consisted of the presentation of 3 negative, 3 neutral and 3 positive sentences.

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