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# Lateralized impairment of the emotional enhancement of verbal memory in patients with amygdala–hippocampus lesion

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**Abstract**

This study investigated amygdala–hippocampus's functional asymmetry in the emotional modulation of memory for stories. Thirty-nine, right-handed, drug-resistant epilepsy patients who had been submitted to unilateral temporal lobectomy (19 left and 20 right) watched either an arousing or neutral version of a story presented audio-visually. The slide sequence was the same in the neutral and arousing version, the narratives were matched for structure and comprehensibility. The set and order of the 11 slide sequence were identical in both conditions. Free recall and recognition measures were taken 2 h after story presentation. Subjects in the TLE group who watched the arousing version recalled more details than the subjects who watched the neutral version ($t(37) = 3.4,\ p < .001$). The group who watched the arousing version recalled more details of the phase 2 of the story ($t(37) = 6.76,\ p < .001$). Scores in both conditions did not differ between control subjects and temporal lobectomy patients. When the right and left lesioned groups' results were analyzed separately, it was observed that the two groups did not differ in their recall of the neutral version. The right lesioned group recalled more items of the arousal than the neutral version ($Z = -3.55,\ p < .001$). However the left lesioned group did not show the memory enhancement for the emotional version, in this group it was only found an enhanced recall of the more pictorial emotional segment of the narrative ($Z = -3.11,\ p < .001$). This illustrates that the right amygdala can influence retention of complex emotional stimuli with verbal and pictorial arousing properties. We concluded that an intact left amygdala–hippocampus is important for enhancement of memory related to emotionally arousing verbal material.


*Keywords:* Amygdala; Hippocampus; Arousal; Emotion; Memory; Temporal lobectomy

## 1. Introduction

There is an extensive body of evidence supporting the view that the amygdala nuclei participate in the consolidation process of emotional information, and that the basolateral nucleus is the major amygdaloid nucleus involved in this phenomenon (e.g., Cahill & McGaugh, 1998; LeDoux, 1993; Sarter & Markowitsch, 1985; Tomaz, Dickinson-Anson, & McGaugh, 1992).

Human and animal studies indicate that stress related hormones and amygdala activation have an effect on memory consolidation. Animal investigations showed that β-adrenergic systems and amygdala activation enhances memory consolidation, and that β-adrenergic receptor antagonists block the memory-enhancing effects of emotional arousal (McGaugh, Roozenddal, & Cahill, 2000). Similar findings have been reported in humans (O'Carroll, Drysdale, Cahill, Shajahan, & Ebmeier, 1999) revealing that noradrenergic simulation with oral intake of yohimbine enhances recall of an arousing version of a story while the blockade of noradrenergic system with ingestion of metoprolol reduces the recall and recognition of the emotional narrative.

Cahill and colleagues (Cahill et al., 1996), in a magnetic resonance functional imaging study (fMRI), reported that subjects with higher levels of amygdala metabolic rate while viewing negative emotional films had a better free recall of these films three weeks after their presentation. LaBar, Gatemby, Gore, LeDoux, and Phelps (1998) corroborated earlier findings with

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humans of the relationship between the reactivity of the amygdala blood flow or metabolism and emotional learning. They demonstrated a significant positive correlation between fMRI signal change in the amygdala during conditioning and magnitude of skin conductance responses during recall, 1–3 months later.

A number of studies have illustrated the role of the amygdala in the recall of declarative emotional memory using similar neutral and arousal versions of stories. Hamann, Cahill, McGaugh, and Squire (1997) presented evidence of a possible dissociation between emotional memory and other memory systems. They showed that in a group of amnesic patients of varying etiology and lesion types there was no impairment in the emotional enhancing effect. Although these patients presented mild to moderate memory deficits on measures of verbal recall they still showed the enhanced recall of the emotional version of a story. Conversely, declarative memory for emotional story was selectively disrupted in patients with bilateral amygdala damage and spared hippocampus (Adolphs, Cahill, Schul, & Babinsky, 1997; Markowitsch et al., 1994).

The amygdala may also have an important role in the retrieval of emotional autobiographical information. Mori et al. (1999) reported that individuals with probable Alzheimer's disease were unable to retrieve episodic old memories about an earthquake in their city, when their amygdalar volume was reduced.

Boucsein, Weniger, Mursch, Steinhoff, and Irle (2001) found that extension of amygdala resection was related to performance on an associative learning task with facial emotional expressions on a sample of temporal lobe epilepsy patients who had been submitted to temporal lobectomy. This finding, viewed in light of the human and animal studies, gives further support for the formulation that the amygdala has a specific modulatory role in memory consolidation. However these authors did not find any significant difference when they compared subjects with left and right side lesions in the associative facial expression learning task.

Investigations have not yielded consistent findings regarding the stimulus modality and amygdala functional asymmetry. Cahill et al. (1996) in a positron emission tomography (PET) study found a strong association between right amygdala activation at the encoding stage and the long-term retention of emotional films. Burton, Gilliam, Flynn, and Labar (1999) investigated recall of affective versus neutral stories with epilepsy patients who had undergone temporal lobectomy. They found that the quality of the recall of an affectively loaded narrative depended on an intact left temporal lobe. Their conclusion indicates that the emotional enhancing effect of verbal material follows the modality specificity of the left hemisphere for verbal memory. On the other hand, Phelps, LaBar, and Spencer (1997) did not find any lateralized impairment of enhanced recall for emotional words in patients who had received unilateral temporal lobectomy, including the amygdala and hippocampus.

Markowitsch (1998), confronted with inconclusive findings regarding the role of the right and left amygdalae in emotional processing, raises the possibility that hemisphere-specific differences in the activation of the amygdala vary according to: type of memory process, stage of memory formation and quality of the stimuli. The right amygdala would be responsible for processing the implicit processes of affective information and the explicit and implicit retrieval of emotion-related information. On the other hand, the left amydala would be more involved in processing threatening stimuli particularly at the encoding stage. Pictorial, image-related stimuli, would be better modulated by the right amygdala while language based processes would involve modulation in the left amygdala.

Collectively, available research data indicate that amygdala lesion can impair recall of emotional information (see for reviews Davidson & Irwin, 1999; Hamann, 2001). However, the functional repercussion of unilateral amygdala damage and the possibility of contralateral compensation in memory enhancement of complex language based emotionally arousing material remains unclear. Lesion studies that pursue these questions may contribute to elucidate the functional basis of asymmetries in the amygdala's activation and the state of the amygdala modulatory function when there is a change in the interconnections within the medial temporal lobe.

In the present study, we investigate the recall of an emotional story in patients with unilateral amygdala–hippocampus lesion. According to previous findings it was expected that, as whole, individuals with temporal lobectomy would manifest the same enhanced recall of the emotional story as controls. However, we expected that individuals who underwent left temporal lobectomy would not demonstrate the enhanced recall of the emotional version of the story when compared to right temporal lobectomy subjects. It was also the goal of the study to examine encoding differences of the emotionally arousing narrative by comparing the recognition of the central and peripheral aspects of the narrative.

We chose to employ a story paradigm with a neutral and an arousing version presented audio-visually. This paradigm had been previously used on a Brazilian sample (Frank & Tomaz, 2000) and on distinct clinical samples (Adolphs et al., 1997; Hamann et al., 1997). It allows for better control for the main effect—the emotional content, in order to minimize interference due to the quality of the material and its repercussion on the clinical sample. Given that the cognitive deficits exhibited by these patients can be quite diverse we matched the experimental groups on selected cognitive variables.