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Brief Report

# Differential effects of emotional arousal in short- and long-term memory in healthy adults☆

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**Abstract**

Recent studies demonstrated important differences between short- and long-term memory mechanisms. Besides, the emotional component has a crucial role in memory formation. This study was carried out to answer whether there is a differential influence of emotional arousal in short- and long-term memory in healthy adults. Thirty-one healthy volunteers were divided into two major groups. In the first group long-term memory (LTM) was evaluated, with the testing session one week after training. The second group was tested 1 h after training, where short-term memory (STM) was evaluated. Each group was divided in to two subgroups. One half of the volunteers was exposed to an emotionally neutral story, and the other half of each group was exposed to a closely matched but more emotionally arousing story. The testing session consisted of a questionary containing 80 questions of multiple choices. The results were evaluated through percentage of correct answers. Results showed that correct answers were increased, in LTM measures, in the subjects that were given the emotional version of the test. In STM measures, no differences were found between the emotional and neutral version. However, the presentation of emotional story caused an emotional reaction in both groups. The lack of effect of emotional arousal in STM suggests that amygdala is not related to STM mechanisms. Further studies using different approaches are needed to elucidate if STM processes are influenced by emotional arousal.


There is little doubt that memory for emotional arousing events is better than for neutral stimuli. This is clearly adaptive, because emotional stimuli, whether pleasant or aversive are generally more important to species survival (Hamann, Ely, Grafton, & Kilts, 1999). Evidence indicates that emotional memories established through the amygdala are impervious to extinction and forgetting processes (Cahill, 1997; Ledoux, 1992). These findings are consistent with the hypothesis that emotional responses influence memory, at least in part, through amygdala by modulating long-term memory storage (Bianchin, Mello-e-Souza, Medina, & Izquierdo, 1999; Cahill & McGaugh, 1996). During and immediately after emotionally arousing or stressful situations, several physiological systems are activated, including the release of many hormones (Roozendaal, Quirarte, & McGaugh, 1997; Stratakis & Chrousos, 1995). Several of these substances like adrenal hormones, corticotrophin, prolactin, vasopressin, and opioid peptides are known to modulate memory storage (Buchanan & Lovallo, 2001; Cahill, 1997; McEwen & Magarinos, 1997; McGaugh, 2000; Newcomer, Craft, Hershey, Askins, & Bardgett, 1994). Evidence indicates that epinephrine and glucocorticoid effects on memory are mediated by influences involving amygdala (Roozendaal, Sapalsky, & McGaugh, 1998). The basolateral nucleus of the amygdala is critically involved in the glucocorticoid influence since lesions or of infusion of B-adrenergic receptor antagonist at this area block the effects of glucocorticoids (McGaugh, 2000). Considerable evidence indicates that amygdala has a crucial role in enhancing the strength of long-term memory for

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emotional events through the interaction of peripheral adrenenergic systems with cholinergic, opioid-peptidergic, and GABAergic systems (Hamann et al., 1999).

There is strong evidence that amygdala is involved in modulating long-term storage, for many reasons, like the compatibility between studies using human subjects and those of animal experiments (McGaugh, 2000). Studies using B-blockers and amygdala lesions showed a reduced effect of emotional arousal on memory (Cahill, Prins, Weber, & McGaugh, 1994). Most current evidence indicates that the amygdala is not a site of storage of memory processes, but has a modulatory function (McGaugh & Izquierdo, 2000). Barros et al. described that drugs that facilitate memory given 3 h posttraining into rat CA1 region reverse the amnestic effect of KN62, an inhibitor of calcium calmodulin kinase II, given into amygdala 0 h after training, but not that of KN62 given into CA1 0 h posttraining (Barros et al., 1999). Additionally, 3-week recall of emotional material is highly correlated with positron emission tomography activation of the right amygdala during encoding (McGaugh, Cahill, & Roozendaal, 1996). Furthermore, studies evaluating the consequences of visual cortex lesions on the acquisition and extinction of fear responses conditioned to visual stimuli showed that the animals failed to extinguish over the period of one month (Ledoux, 1992). This suggested that emotional memories involving subcortical inputs to the amygdala are highly resistant to extinction. The amygdala is believed to influence memory through its direct connection with hippocampus and entorhinal cortex (Izquierdo & Medina, 1997). This connection appears to have a time-limited role in memory formation.

Recent findings described differences between short-term memory (STM) and long-term memory (LTM) in step-down inhibitory task, suggesting that different mechanisms are involved in each one (Izquierdo et al., 1998a; Izquierdo, Medina, Vianna, Izquierdo, & Barros, 1999). Short-term memory was defined as that measured while LTM becomes effectively consolidated, i.e., in the first 3–6 h after acquisition (Izquierdo & Medina, 1997). During this time, biochemical events take place in the hippocampus and elsewhere, which culminate by gene transcription and protein synthesis that are necessary for LTM consolidation. This definition of STM stems from the classical studies of James and McGaugh (James, 1890; McGaugh, 1966). Long-term memory becomes fully consolidated only several hours after acquisition. Many studies suggest that this process involves hippocampus, entorhinal cortex, and other cortical regions and that it is modulated early after training by the amygdala (Cahill & McGaugh, 1996; Izquierdo & Medina, 1997). Emerging evidence from Bianchin et al. suggests that the influence of amygdala on long-term memory occurs independent of working memory and short-term memory and that amygdala is uninvolved in the last two kinds of memory in step-down inhibitory avoidance task (Bianchin et al., 1999).

Considered together, these findings provide support to investigate the influence of emotional arousal on STM and LTM in healthy adults. Since amygdala, that appears to mediate most of the emotional influence on memory, have been shown different involvement in STM and LTM, this allows to evaluate the importance of the emotional content to memory formation in these two different moments in the time window. According to the memory consolidation hypothesis and experimental animal data, we expect that emotional arousing increases long-term memory, possibly through amygdala modulation of hippocampal activity, but do not affect short-term memory, since little consolidation has taken place at this period and the two kinds of memory may have different mechanisms.

Thirty-one healthy volunteers (male, University students, age between 18 and 30) had an individual explanation about study objectives, which persuade the subjects to believe it was a cardiologic physiology evaluation in variable conditions. Then, the informed consent was obtained. University Hospital Ethics Committee approved the protocol. Subjects were exposed to an emotionally neutral story, or a closely matched but more emotionally arousing story (Cahill et al., 1994). The stories were presented as a brief (about 5 min) narrated slide show. The entire presentation consisted of 11 slides accompanied by narration, which could be emotional or neutral (Cahill et al., 1994). The story was divided into three phases: the first including the slides 1–4, the second including slides 5–8, and the final with slides 9–11. In phase 1 the narration was identical in the neutral and in the emotional version of the story, in phase 3 it was nearly identical. The emotionally arousing narration occurred in the middle (phase 2) of the story. Immediately after training, each subject was asked to match in a 0–10 scale how emotional he thought the story was. Subjects watched the slide presentation individually and heart rate and blood pressure were measured while viewing the story. They were told that the study was conducted in order to evaluate physiological responses to different types of stimuli. One hour or one week later volunteers were submitted to a surprise memory-recall test. Subjects were divided into two major groups in which the difference between them was the time they did the testing session. In the first group ($n = 14$) long-term memory was evaluated, with the testing session one week after slide show. The second group ($n = 17$) was tested 1 h after training, considering STM. In the period of time between slide presentation and test session, the group that had to wait 1 h was conducted to a neutral environment where they were allowed to read books or previous selected magazines and watch some documentary on VCR. The group that performed the memory