

Review (Narrative)

Emotionally Stimulated Persistent Memory

Shine Parker, M.Sc.

SUMMARY

Most things in life are forgotten. Emotional stimulation can improve the storage of memory, which helps people to selectively build lasting memories of important experiences. Nervous system-mediated emotional arousal and memory are very closely linked. The adrenaline and corticosterone released during emotional stimulation can regulate the consolidation of long-term memory. The amygdala plays a key role in regulating the effects of these stress hormones on the body. Stress-induced activation of the amygdala and its interaction with other relevant brain regions that process memory are the key to ensuring that emotionally meaningful experiences are remembered. ■

KEYWORDS

Memory; Emotional Stimulation; Amygdala; Stress Hormone

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Author Affiliations: Author affiliations are listed at the end of this article.

Correspondence to: Ms. Shine Parker, M.Sc., Stress Center, The Merkel Brain Lab, Austin, TX 78660, USA.
Email: s.parker@aol.com

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LEARNING and memory are vital to survival, and memory enables people to predict what might happen and change behavior as a result. The brain cannot accommodate every detail in life, nor can it produce equal memories of these details. Memory is a basic cognitive process that promotes all other important cognitive functions. People cannot think without memory, and most animals can show their memory of experience. However, the memory of all experiences cannot be quantified. The memory of some new experiences can last for a long time because they are easily processed by the brain and fit well with existing memories (1). Memory is strengthened by repetition and retrieval (2). This article summarizes the research progress on the role of amygdala and emotional stimulus in the brain's participation in persistent memory retention.

EMOTIONAL STIMULATION AND LASTING MEMORY

Emotional experiences are easier to remember. Some unpleasant experiences: such as a car accident, a robbery will be more clearly remembered than daily chores (3). Happy moments such as birthdays, holidays and weddings are also well remembered. The intensity of memory of an event varies with the emotional significance of the event. People who were close to the area during the 1989 San Francisco earthquake remembered better months later than residents of Atlanta (4). Three years after the "9.11" incident, those who were in downtown Manhattan at the time of the attack had deeper memories of the attack than those who were miles away from the incident (3).

Memory is assisted by things that impress people, such as passion, fear, surprise, shame, and happiness. The time-dependent process of memory consolidation is regulated by conditioned stimuli after learning. Studies have shown that low-intensity CNS stimulation in mice or rats can improve memory immediately after training (5). Emotional stimulation can induce the release of adrenaline and cortisol (corticosterone in rats). During the memory consolidation process, the emotional training experience can increase the levels of these hormones. Adrenaline and corticosterone administration in rats after various training sessions can enhance memory (6, 7). In addition, adrenergic and glucocorticoid receptor antagonists can block the effects of emotional stimulation and adrenal stress hormones on memory consolida-

tion (8, 9, 10). Many experiments that study the effects of stress hormones have involved memory related to stress training. For example, giving stress hormones after training with less stress stimuli can improve memory, including reward memory (11). It has also been reported (12): Multi-factor chronic stress can cause changes in neurotransmitters, neurohormones, and hypothalamic-pituitary-adrenal axis in animals, leading to impairment of animal behavior and learning and memory.

AMYGDALA AND MEMORY PROCESS

Amygdala Activation and Memory Regulation

Adrenal stress hormones enhance the brain's memory of the events that cause it to be released. Studies have shown that the effects of adrenaline on memory may be triggered by activation of peripheral vagus nerves projected into the brain (13). Direct electrical stimulation of the ascending vagus nerve after learning can enhance memory (14). Cortisol enters the brain freely and activates glucocorticoid receptors in the brain.

The amygdala may act as an important brain region that regulates stress hormones, affecting memory consolidation. Studies have found that rats undergo short-term low-intensity electrical stimulation of their amygdala after training can enhance memory (15). Earlier studies have shown that injection of β -adrenergic receptor antagonists into the amygdala after training can impair memory consolidation and meanwhile injecting norepinephrine can block the damage (16). Another study reported that systemic administration of adrenaline can lead to the release of norepinephrine in the brain (17), and the increase in adrenaline that causes memory consolidation can be blocked by injecting propranolol into the amygdala (18). Studies have suggested that noradrenaline activation in the lateral region of amygdala (BLA) of the amygdala after animal training can improve the brain's ability to remember training experience (19). Injecting β -adrenergic receptor antagonists into the amygdala of rats after training can weaken memory and block the effect of systemic administration of corticosterone and epinephrine to improve memory (20). These findings indicate that glucocorticoid-induced memory consolidation requires activation of the amygdala norepinephrine receptor. The activation of norepinephrine receptors by emotional stimulation

seems to make it possible for glucocorticoids to regulate memory consolidation (21).

Many related studies have shown that emotionally stimulated training experience may increase the release of norepinephrine in the amygdala, and foot shock training increases the release of norepinephrine in the amygdala (22). Rats with significantly increased release showed better Memory retention (23). In addition, some memory-enhancing drugs, including gamma-aminobutyric acid (GABA) energy and opioid peptide receptor antagonists can increase the release of norepinephrine from the amygdala (24).

EFFECT OF AMYGDALA ON OTHER BRAIN REGIONS

The amygdala is richly associated with the brain region including the cortex and is involved in different aspects of the memory process. The amygdala affects memory consolidation by projecting nerve fibers into other brain regions (25). Studies have shown that hippocampus participates in spatial learning and memory (26, 27), and caudate nucleus participates in response-related spatial cues learning and memory (28). Packard et al. (29) found that in the water maze experiment, activation of the amygdala after training can enhance the animals' memory of position and clue learning. McIntyre (30) found that in rats, activation of norepinephrine receptors in the basolateral region of the amygdala enhances memory consolidation and increases expression of activity-regulated cytoskeletal (Arc) in the hippocampus. These studies indicate that Arc is involved in regulating synaptic plasticity and memory consolidation (31).

Emotional Stimulation, Adrenal Stress Hormones and Human Memory

Studies have shown that the effects of emotional stimulation on humans are consistent with animals. Emotional activation during or after learning can enhance long-term memory that is strongly related to adrenaline and cortisol. However, experiences that affect memory need not be intense emotions. Studies have shown that when subjects are exposed to pictures and text with mild emotional content (whether positive or negative), their memory enhancement effect is significantly higher than pictures and text without emotional content (32).

Therefore, the observation of emotionally stimulated pictures can enhance memory (33).

Emotional Stimulation Regulates Memory Consolidation

Studies have shown that subjective emotional stimulation after learning improves memory (34). Participants watched a short episode of comedy or tragedy that could stimulate emotions immediately or after a certain period of time (maximum 45 min) after learning a group of words. Evaluation was made one week later, and the conclusion was that the video was watched within 30 minutes after learning whether it was tragedy or comedy Can enhance memory. College students watched emotional video clips after the lecture, and the test results after 2 weeks were significantly better than those who did not see the video (35).

Numerous studies have shown that the effects of emotional stimulation on memory consolidation are related to adrenaline and cortisol. Subjects were given adrenaline receptor antagonist propranolol before viewing a set of pictures that stimulated emotions. Tests a week later showed that the effects of emotional stimulation on memory enhancement were blocked (36). Show the subject an emotional picture immediately after giving adrenaline or cold pressure stress (induced by placing one hand in ice water, causing the release of adrenaline and corticosterone), which can improve the subject's picture Memory (37, 38). Hupbach et al. (39) reported that the emotional stimulus induced by cold pressurization stress after a memory retrieval test increases salivary cortisol and enhances memory of the test content a few days after the test.

It has been reported that activation of adrenaline receptors selectively affects memories produced by emotionally-stimulated stimuli (40). Cold pressurization stress induction after listening to some neutral and emotional words can selectively improve emotional word memory on the second day after the test. The levels of corticosterone and salivary alpha-amylase (the two biomarkers activated by the noradrenergic system) immediately after cold stress were found to be highly correlated with subsequent memory performance (41). In addition, Segal et al. (42) pointed out that the saliva α -amylase level was measured immediately after observing a series of emotional and neutral pictures, and it was found in a 1-week memory retention test study that this level was comparable to that of the subject. The memory of these emotional pictures has obvious selection correlation. The salivary α -amylase levels measured after exposure to emotionally stimulated pictures are

also strongly correlated with subsequent memory evaluations of successful recognition of pictures seen from similar pictures (43). This discrimination involves the hippocampus (44).

Effects of Emotional Stimulation on Memory Including Activation of Amygdala

In the initial study using PET imaging, Cahill's (45) activation of the amygdala caused by watching emotionally stimulated movies was highly correlated with memory of the movies tested 3 weeks later. Subsequent research using positron emission tomography (PET) imaging technology has also been reported similarly (46). The magnetic resonance image (MRI) imaging technology was used to discover the relationship between amygdala activation and memory that changes directly with the intensity of emotional activation during learning, and it is not critical whether the emotional state is positive or negative (47). The evidence provided by imaging studies is consistent with evidence obtained from animal studies: The effect of emotional activation on long-term memory consolidation involves the interaction of the amygdala with other brain regions during learning, including the hippocampus (48, 49). Imaging studies of the human brain using functional MRI tech-

niques have found that the effects of emotional arousal on memory involve activation of the noradrenergic system of the amygdala. Propranolol blocks the activation of amygdala and subsequent memory of emotionally stimulated stimuli (50). The administration of the adrenergic drugs yohimbine and hydrocortisone can enhance the activation of the amygdala and hippocampus and thus improve memory (51).

CONCLUSION

In summary, most people's brains cannot accommodate every detail in life, nor can they produce equal memories of these details. Selectively remembering more important experiences seems to be the best strategy. Epinephrine and corticosterone released during emotional stimulation can regulate the consolidation of long-term memory. Amygdala may affect memory as an important brain region that regulates stress hormone-related consolidation. The projection of neurons in the brain is complex, and there are many types of neurotransmitters. The molecular mechanisms and pathways through which they coordinate with each other in memory-related brain regions and nucleus groups to complete durable memory need further study. ■

ARTICLE INFORMATION

Author Affiliations: Stress Center (Parker), The Merkel Brain Lab, Austin, TX 78660, USA

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