Relationship between Emotion & Memory and its Neural Mechanism

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Abstract. Since the principal of 'flash bulb memory' turned out, a growing body of research has examined the connection between emotional valence and memory. The literature research focuses on articles published in recent years to summarize both the consensus and debates generated over experiments and reflections. A consistent finding across studies is that emotional valence of the information saliently enhances memory effect than neutral ones, known as emotional enhancement effect (EEM). It has been widely shown that EEM effect is particularly linked to the interaction between amygdala and hippocampus. Additionally, emotional valence of contents which shows high levels of arousal, creates more opportunities to developing false memory. However, the separate roles of positive and negative valence on memory are not clear due to the conflicted findings between various studies. In conclusion, the reviewed literature has important implications for clinical therapy, forensic psychology and educational psychology. Also, it is exemplary for discipline-interactive studies.

Keywords: Emotional valence; memory; emotional enhancement effect; arousal; false memory.

1. Introduction

Memory is not a neutral historian but a poet the filter of emotions. Trace to the research of flashbulb memory, scientists have already realized and successively dedicated into the study of emotional valence and memory for approximately half a century. The enduring belief of people that emotionally charged memory is processed and retrieved in advantage comparing to those information with neutral valence is verified to be plausible, but in fact incomplete. An prioritization and systematic distortion of memory coding can be explained by the mysterious mechanism in the brain, which is mediated by the dialogue of amygdala and hippocampus. This mechanism shapes a intriguing fact, that what the individual remembers is never the event itself, but the ripples it arises in the heart at the very moment.

In the daily life, understanding the relationship between emotion and memory is helpful for creating a moderate emotional learning environment for students. Also, it can be applied to the therapy of PTSD, depression and anxiety. What's more, it is useful in judicial area effective eyewitness memory.

2. Core Concepts

2.1. Emotional Valence

Emotional valence is a feature of emotions that determines their emotional effects. Positive valence relates to 'goodness'. Desirable words such as 'kind' and 'wonderful' have positive valence. In contrast, negative valence connects to 'badness'. Words with negative valence includes 'death', 'burglar'.

2.2. Memory

Memory is an information processing system in which information is encoded, stored and retrieved when required. It is an aspect of mind which is composed of sensory memory, short-term or working memory and long-term memory. A short or long-term memory is either explicit or implicit. In the type of explicit memory, there is episodic memory, semantic memory and autobiographical memory.

Episodic memory is the memory for events. Semantic memory is the memory for knowledge or facts. Autobiographical memory includes all of an individual's own life experiences. Implicit memory consists of procedural memory, semantic memory and autobiographical memory. Procedural memory is the memory for skills, such as the skill of playing a violin. Sensory memory is taken in by an organism's sensory receptors and is transferred to certain sensory brain areas. The reception of an sensory stimuli involves a process of selective attention because there are myriads of stimulus in every moment. The two types of sensory memory are iconic (visual) memory and echoic (auditory) memory.

Sensory memory lasts for 0.5 seconds or less for iconic (visual) memory, less than a second for haptic (touch) memory and about 3 to 4 seconds for echoic (auditory) memory, with extremely limited capacity.

With the effect of attention, sensory memory will last long enough to convert to short-term memory (STM). This is called encoding. It can lasts for some seconds or minutes. It has a relatively small capacity. The information stored in short-term memory can be visual, acoustic, or semantic, depending on the encoding process [1].

The transition of short-term memory to long-term memory (LTM), known as consolidation, primarily involves hippocampal activation and cortical integration. The long-term memory can be stored for a very long time and it also has a very large capacity.

2.3. Retrieval and Recognition

Retrieval or recall refers to the process of searching and bringing back the information to individual's consciousness. Recall can be serial, free or cued, each providing unique insights into the retrieval process deep into the brain regions. Serial recall is recalling stored information in order. Free recall is to recall all the items in a certain order. Cued recall occurs when paired items are learned. As one item of a pair is shown, another item has to be recalled. Recognition is the identification of information that was encountered previously. When an individual is recognizing information, a sense of familiarity is evoked.

2.4. False Memory

Human memory is reconstructed in brain area during the process of encoding and consolidation. False memory means that remembrance cannot match the actual information or event. Leading information such as misleading questions or suggestive phrasing, can be responsible for the formation of false memory [2]. False memory is especially significant for judicial area, since it causes the majority of wrong convictions.

2.5. Other Important Concepts

There are two concepts needed to be clarified and differentiated. The first one is the emotion valence of memory. It is the emotion triggered by a memory itself. Another concept is the emotional state when an individual is retrieving an episode or self experience. The emotion of the individual in this situation maybe not determined by the content of the memory, but the internal or external conditions at the current moment.

3. Mutual Relationship between Emotional Valence and Memory

According to previous studies, it is shown that memory is reconstructive. Therefore, factors like emotion valence can interfere the consolidation and retrieval of long-term memory as autobiographical or episodic memory.

It is verified by many studies that long-term or short-term memory with a positive or negative valence has an advantage on retrieval, known as emotional enhancement memory effect (EEM) [3]. In the study, both the tasks on recognition memory and free recall were used to figure out the impact

of words' emotional valence on memory. It was the first study that used a large sample of vocabulary to conduct an experiment in emotion-memory area.

An U-shaped relationship was founded, which indicates that the average score is higher in the memory of positive and negative words than in the memory of neutral words. In addition, it shows a linear relationship between arousal level and memory performance. As the arousal level of the word increases, the recognition score increases as well, conforming a relationship of the monotonic function. Arousal differs from valence. Based on the research on EEM, researchers also interest in the comparison of neural mechanism behind emotional memory. A literature review demonstrates that an individual's positive emotion to a memory maintains the same over time, while the individual's negative emotion to a memory fades as time goes on [4]. However, it is shown in the research that the most prevalent finding of experiments is that negative memories are more durable than positive equivalents. In other words, negative memories are recalled more smoothly and detailed after a long interval of time. Actually, it seems debatable because most of the studies focuses on the impact of negative memory because of the ease for researchers to create a negative stimuli rather than a positive one.

It is founded soon that amygdala, a particularly emotion-related brain region interacts with hippocampus, responses to both positive and negative stimulus. Similarly, according to Kensinger, this interaction enhances the possibility for visual details to be encoded into memory [5].This finding is concluded as emotional binding model for emotional memory, which suggests that Amygdala allows for item-emotion bindings and the memory effect with its help transcends the item-context binding created only by hippocampus itself. Basically, It is proved that the encoding of positive and negative memory depends on different processing of brain. The negative emotion of memory activates more sensory areas during encoding which helps the individual to remember the specific sensory details of the event(For example, a purple umbrella with blue patterns). The positive emotion of memory activates conceptual areas, such as the prefrontal cortex, during encoding, which enhances the gist-based representation of the event. This theory proposed as the negative emotional valence enhances recapitulation (NEVER) model, which holds the idea that negative valence increases the possibility of sensory areas to be incorporated into emotional memory networks, thus the sensory details are valued and encoded.

Additionally, the study suggests that the essence of EEM is that core details are enhanced in priority, while edged details are neglected. This is known as arousal biased competition (ABC) model. It is demonstrated in the model that, the arousal level helps the emotional information to win over more processing resources than neutral information. The researcher of this literature review hypothesizes that the reason of this phenomenon origins from the loading effect. During the encoding of the memory, attention is allocated more to those core details which leads to an advantage in memory processing as consolidation. In other words, the encoding intensity plays an important role in memory processing. Another perspective towards arousal can be explained by the neuromodulatory model of emotional memory reinstatement. It is said that arousal, which releases norepinephrine and novelty seeking, which releases dopamine can be applied to predict both the recovering patterns of neurons and the quality of emotional memory retrieved better than the valence of information itself.
There are three models of emotional memory that each corresponds and explains the EEM effect for different stages of memories. Mediation model illustrates that attention, distinction and and organization are adequate to account for short-term EEM. It is suggested in the modulation model that amygdala is responsible for adjusting medial temporal lobe consolidation of encoded memory and lets the occurrence of delay-dependent EEM to happen. According to the emotional context maintenance and retrieved (eCMR) model, memory is tightly bonded to its emotional valence and temporal context. Therefore, the reproduction effect of emotional background is salient in spite of a long-term interval of time.

Despite of the general and biological mechanism of emotional memory, interpersonal differences also influences the memory of emotional events, too. The personal connection to the event, cognitive resource and personality accounts for the different memory effect among populations.

Continuing the influence of personal disparities on emotional memory, a constructive study of 'flashbulb memories' firstly proved the role of personal linkages to a particular event on the memory effect [6]. Latter, it is appears that people hold a great confidence on the detail of events, in spite of the memory fading [7].

Nostalgia plays an essential role in both memory and emotion domains, serving as a psychological resource that fosters self-continuity and emotional regulation. Nostalgia is always expressed as autobiographical memory by individuals [8]. It is a phenomena that particularly displays a process in which emotional valence and memory effect interacts with each other mutually. One of the evidence is that people with nostalgia of negative valence are reported to have more negative emotions such as loneliness and depression. This negative emotion of individuals enhances the phenomenon of nostalgia in further. but they mutually depend on each other.

4. Emotional Valence and False Memory

Scientific devices like EEG make great contributions to the area of neuroscience. It has been proved that the formation and callback of false memory is highly influenced by emotional factors. Via using AI model to simulate the formation of false memory helps scientists to more accurately understand the specific mechanism of false memory, then explore the roles of emotional valence. According to the AI model in the study of Mahalakshmi, groups processing information of different emotional valence show different activities in brain regions during callback process [9]. The positive emotion group shows significant activation in the frontal lobe, particularly the left side, which suggests enhanced logical reasoning and associative processing. This activation results in enhanced analytical reasoning and associative retrieval. As for negative emotion, it activates the occipital lobe which indicates the existence of the mode for cognitive inhibition. This mode is related to mitigated rate of false memory emergence.

However, some studies demonstrates a totally contrast perspective compared to the results generated by the AI model. It appears in the study of Joshi, Rathore& Verma that negative contents induces more false memory than contents of other emotion, since people can easily recall the core messages and seize semantic correlations between the valence of current information and the memory content [10]. The evidence is provided both by DRM paradigm and misinformation paradigm.

Overall, it can be inferred that whatever the emotional valence is, the rise in arousal level increases the probability to develop false memory. Especially when the emotional valence of the stimulus corresponds to the emotional state of the individual at the moment, the individual will be more prone to have false memory. This is known as spreading activation theory, which posits that the activation of one concept motivates the activation of related concepts through associative networks. A hypothesis of spreading activation theory holds the view that the activation of one concept in the memory evokes other concepts, forming inter-connecting information networks. This is the reason for why false memory occurs.

5. Discussion and Suggestion

Basically, the effect of emotional valence on memory compared to neutral valence is distinct. Nevertheless, the comparison between the effect of positive valence and effect of negative valence can be experimented in further. At the same time, more studies that focuses on the impact of current emotional valence on memory are needed.

The investigation of the mechanism behind false memory displays a new view in conducting studies with discipline intersection (For example, using AI to model how emotional valence can influence false memory provides an template in cognitive science and artificial intelligence). Therefore, more interdisciplinary studies can be carried out to explore insightful ideas to modern topics.

The study particularly illustrates how artificial intelligence can accelerate the development of neuroscience [9]. The accuracy and convenience that the AI model provided is impressive. It is a great idea for future studies to continuously improve AI models to profoundly explore the impact of emotional valence on memory mechanism.

The findings provide valuable insights for the field of forensic psychology. Highly activated situation and deliberate guiding content need to be avoided in eyewitness. Also, the flashbulb effect can be applied when the witnesses are not able to recall the situation because the personal link to the event may trigger the impression to the scene. For example, the question of 'which position were you at when the car accident occurred' can be ask to help the retrieval of memory. Besides, it should be aware that the accuracy of the witness' memory maybe not exactly though the witness deeply believes the authenticity of their memory.

The points in the studies of autobiographical memory can also be coalesced into suggestions for clinical psychology area. Since the mutual influence between nostalgia and emotional states, an active recall of the patient's autobiographical memory with positive valence can be guided by the therapist. This may ease the painful feelings of patients with depress or anxious symptoms and improves the treating effect. What's more, a converting of self perspective to observer perspective can be incorporated into the treatment to abbreviate the subjective negativity of the patient's memory.

As for the educational settings, a moderate emotional learning environment, can be created. The adjustment of text contents' arousal level to be higher can reduce boredom caused by constant neutral information. However, another crucial consideration is that both negative and positive valence of the content lead to potential false memory. Therefore, a dynamic balance can be modulated by scientists to maximizes the effect of learning.

6. Conclusion

Overall, both the negative and positive valence of the memory content enhances the memory effect, which signifies that the EEM effect has been established by myriads of studies. However, the respective roles of positive and negative valence remain debatable, suggesting that further empirical studies are needed to clarify their distinct neural and behavioral impacts. There is also an essential extraneous variable--interpersonal differences, that can significantly affect the memory.

Furthermore, when individuals become agitated, their accuracy in memory fluctuates. This may results in significant impacts, such as wrongful conviction and clinical discomfort induced by false memory. Meanwhile, this mechanism also indicates the path for improvement to minimize the potential harm caused by false memory.

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