Acta Psychologica 157 (2015) 56–64

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Timing matters: Negative emotion elicited 5 min but not 30 min or 45 min after learning enhances consolidation of internal-monitoring source memory

Bo Wang [a,*], Bukuan Sun [b]

[a] Institute of Economic Psychology, Department of Psychology, School of Social Development, Central University of Finance and Economics, Beijing 100081, China
[b] Fuqing Branch of Fujian Normal University, Fuqing 350300, Fuzhou Province, China

ARTICLE INFO

Article history:
Received 21 August 2014
Received in revised form 10 February 2015
Accepted 11 February 2015
Available online 25 February 2015

PsycINFO classification:
2343
2360

Keywords:
Negative emotion
Elicitation delay
Item memory
Internal monitoring
Source memory
Memory consolidation

ABSTRACT

Two experiments examined the time-dependent effects of negative emotion on consolidation of item and internal-monitoring source memory. In Experiment 1, participants ($n = 121$) learned a list of words. They were asked to read aloud half of the words and to think about the remaining half. They were instructed to memorize each word and its associative cognitive operation ("reading" versus "thinking"). Immediately following learning they conducted free recall and then watched a 3-min either neutral or negative video clip when 5 min, 30 min or 45 min had elapsed after learning. Twenty-four hours later they returned to take surprise tests for item and source memory. Experiment 2 was similar to Experiment 1 except that participants, without conducting an immediate test of free recall, took tests of source memory for all encoded words both immediately and 24 h after learning. Experiment 1 showed that negative emotion enhanced consolidation of item memory (as measured by retention ratio of free recall) regardless of delay of emotion elicitation and that negative emotion enhanced consolidation of source memory when it was elicited at a 5 min delay but reduced consolidation of source memory when it was elicited at a 30 min delay; when elicited at a 45 min delay, negative emotion had little effect. Furthermore, Experiment 2 replicated the enhancement effect on source memory in the 5 min delay even when participants were tested on all the encoded words. The current study partially replicated prior studies on item memory and extends the literature by providing evidence for a time-dependent effect of negative emotion on consolidation of source memory based on internal monitoring.

1. Introduction

Episodic memory is composed of two elements, one of which is item memory, which refers to memory for a piece of information itself (e.g., a word or a picture) and is usually tested by free recall and recognition. Another element of episodic memory is source memory, which refers to the contexts under which a piece of information was acquired (e.g., the font color of a word or spatial location of a picture) (e.g., Doerksen & Shimamura, 2001; Johnson, Hashtroudi, & Lindsay, 1993; Kensinger & Corkin, 2003; Slotnick, Moo, Segal, & Hart, 2003; Wang & Fu, 2011). According to Johnson et al. (1993), source memory can be based on three types of monitoring: external monitoring (e.g., distinguishing between memories for what one saw and what one heard), internal monitoring (distinguishing between what one thought about and what one read aloud), and reality monitoring (distinguishing between what one saw and what one imagined).

Studies have shown behavioral dissociation between item and source memory. For instance, participants had better memory for items embedded in bizarre sentences than embedded in common sentences, but their source memory (for spatial locations) was not affected by bizarreness (Macklin & McDaniel, 2005). Studies also showed better item memory for emotional words relative to neutral words; however, no reliable difference was observed in source memory for these two categories of stimuli (Davidson, McFarland, & Glisky, 2006). Furthermore, there has been evidence showing neural dissociation between item and source memory such that these two memories respectively depend on functions of the medial temporal lobe and the frontal lobe (Glisky, Polster, & Routhieaux, 1995; Janowsky, Shimamura, & Squire, 1989).

Memory consolidation refers to the process through which an initial fragile memory trace gradually becomes stable over time, or the process via which a labile short-term memory undergoes the transition into long-term memory (Dudai, 2004; McGaugh, 2000). The success of this transition has been shown to be dependent on the hippocampus. For instance, although patients with damage to the hippocampus had great difficulties in forming new memories, they tend to have intact memory for remote past (Squire, 1992). It has thus been proposed that at an early stage when memory has been newly formed, retrieval of memory traces

* Corresponding author at: 39 South Xueyuan Road, Haidian District, Beijing, 100081, China.Tel.: +86 10 62288653.
E-mail address: 709534442@qq.com (B. Wang).

http://dx.doi.org/10.1016/j.actpsy.2015.02.006
0001-6918/

depends on the hippocampus; with the passage of time memory traces are gradually transferred to the neocortex and the corresponding memory retrieval eventually becomes independent of the hippocampus (Squire & Alvarez, 1995).

Memory consolidation can be subject to the influences of many factors such as sleep (Alger, Lau, & Fishbein, 2012), muscle tension (Nielson, Wulff, & Arentsen, 2014), smoking (Colrain, Mangan, Pellett, & Bates, 1992), stress hormones (e.g., Roozendaal, 2000), and progesterone levels (Felmingham, Fong, & Bryant, 2012), but one critical factor that has gained increasing attention is emotion induced after learning. In fact, ample evidence has shown the enhancement of post-learning emotion on consolidation of item memory. For instance, in a study by Nielson, Yee, and Erickson (2005), participants learned a word list and then were assigned into a control or a negative condition, in which they respectively watched a 3-min emotionally neutral video (about tooth brushing) or emotionally negative video (about dental surgery). The results showed that free recall performance at a 30 min or 24 h delay test was significantly higher in the negative than in the control condition. In addition, recognition memory in the 24 h delay was also significantly better in the negative than in the control condition. Because emotion was induced after learning, thus ruling out any effect on attention or encoding, the above study suggests an enhancement of negative emotion on consolidation of item memory. Such an enhancement effect has been found in a number of other studies (e.g., Liu, Graham, & Zorawski, 2008; Nielson & Arentsen, 2012; Nielson & Meltzer, 2009; Nielson & Powless, 2007; Wang & Fu, 2010). In addition, it has been shown that post-learning positive emotion, whether elicited by intrinsic reward (Nielson & Bryant, 2005) or by a comic video (Nielson & Powless, 2007), can enhance consolidation of item memory and the enhancement effect has been demonstrated to remain whether the learning stimuli are negative or positive (Nielson & Powless, 2007, but see Liu et al., 2008).

However, the majority of the prior studies used only item memory tasks, so there is a question: Does the enhancement effect extend to consolidation of source memory? This question has been investigated. In a study by Wang and Fu (2010), participants learned a list of words along with their font colors. After an immediate test, they watched a neutral, positive or negative video. A 25-min delay test showed that post-learning negative emotion enhanced consolidation of item memory (measured by delayed recognition memory) only in females; nevertheless, they found little effect on consolidation of the external-monitoring source memory (for two font colors of words). Another study by Smeets et al. (2006), however, found that post-learning stress enhanced consolidation of both item and source memory (based on internal monitoring). Although it is difficult to treat stress and emotion as identical, the finding from Smeets et al. (2006) may provide insights into the effect of post-learning negative emotion.

Although the above studies have indicated the enhancement of emotion particularly on consolidation of item memory, it is unclear whether the enhancement effect depends on the time that emotion is elicited. Abundant evidence from animal studies indicates that there is a time window for a post-training intervention (e.g., injection of drugs) to have a modulation effect. In a study by Gold and van Buskirk (1975), rats received injection of epinephrine immediately, 10 min, 30 min, or 2 h after training. A 24 h-delay test showed that, relative the control rats that received injection of saline, rats that received injection of epinephrine immediately or 10 min, but not 30 min or 2 h, after learning had significantly better memory performance. This time-dependent effect of post-learning drug administration was also observed in other studies, but it seems that the time window varies depending on the specific substance injected. Rutten et al. (2007) examined the effects of different phosphodiesterase inhibitors (vardenafil, rolipram and BAY 60-7550), which were administered directly after, 1 h, 3 h and 6 h after the first trial. A 24 h delay test showed that vardenafil had an enhancement effect only when administered directly after the first trial; rolipram showed an enhancement effect only when administered 3 h after the first trial; for BAY 60-7550 to have an enhancement effect, however, the administration needed to be conducted either directly or 3 h after the first trial. The above studies have provided important insights into the time-dependency in the effect of post-learning intervention of drugs on memory consolidation, yet little has been known about the generalizability of the time-dependency observed in animals to humans.

Studies have shown that in humans there is also time dependency in the effect of post-learning intervention on memory consolidation. For instance, Nielson and Powless (2007) found that post-learning negative and positive emotion enhanced consolidation of item memory for a word list only when emotion elicitation occurred immediately, 10 min, or 30 min, but not 45 min after learning. This time-dependency has also been replicated in a study by Judde and Rickard (2010), in which music was used to elicit emotion. Participants who listened to emotional music 20 min, but not immediately or 45 min after learning, had better delayed recognition memory than the control group who did not listen to music. Therefore, in humans as in animals, there is also a time-dependent effect of post-learning intervention.

It can be seen from the above evidence from animal and human studies that the time window for post-learning intervention differs widely depending on factors such as learning tasks and type of intervention (e.g., drugs versus emotion). Different studies seem to suggest different relationships between the intervention delay (i.e., interval between the end of learning/training and beginning of intervention) and delayed memory performance. The extant human evidence, however, seems to suggest that post-learning emotion has an enhancement effect when induced up to 30 min after learning. Importantly, 45 min after learning there seems to be a stable boundary where emotion loses its effect on memory consolidation. Nevertheless, as demonstrated by animal studies, the effect of intervention may be contingent upon memory tasks. However, the prior studies (Judde & Rickard, 2010; Nielson & Powless, 2007), which showed a time-dependent effect of emotion, only used tasks of item memory. In addition, the studies (e.g., Smeets et al., 2006; Wang & Fu, 2010) which indeed examined source memory did not investigate whether the delay of post-learning intervention can be modulatory. Therefore, the following questions remain: Does the time-dependent effect on consolidation of item memory extend to consolidation of source memory? If so, is the pattern of time-dependency the same as that for consolidation of item memory? Specifically, is 45 min after learning still the boundary where emotion has no effect?

In an attempt to provide answers to the above questions, the current study with two experiments examined the effect of post-learning negative emotion on consolidation of both item and source memory. The importance of the current investigation lies in at least two aspects. First, source memory is an integral element of episodic memory. Despite the abundant studies on the effect on the consolidation of item memory, it is by collecting evidence regarding source memory that a comprehensive understanding of the effect of emotion on consolidation of episodic memory can be achieved. Specifically, if it turns out that differential patterns exist for consolidation of item versus source memory, then it is important to establish a theory on consolidation of source memory separate from the theory based on consolidation of item memory. Second, it has been suggested that post-learning emotion can be used as a strategy of memory intervention (Nielson & Powless, 2007). In order to have a desired effect of intervention, it is crucial to understand whether the enhancement effect on consolidation of item memory can be generalized to consolidation of source memory. In educational settings, students may be required not only to remember a piece of information, but also to remember the corresponding contextual details. Without the knowledge regarding whether post-learning emotion has similar or differential effects on consolidation of item memory and source memory, it can be fruitless or even counter-productive to elicit post-learning emotion for a task that entails source memory, in a way that is beneficial for item memory. Therefore, it is of practical significance to understand whether the effect of post-learning emotion can be contingent upon the nature of a memory task.