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ORIGINAL ARTICLE

Different effects of feedback-induced emotion and material-induced emotion on memory

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Abstract
The function of emotion in enhancing memory has been proven by a large number of studies. However, previous studies mainly used emotional materials to induce emotions, and far fewer studies have examined how neutral stimuli and emotional event connections affect memory. In Experiment 1, the feedback from the results was used as an emotional event to explore the impact of connected emotions on memory. In Experiment 2, emotional materials were used to induce emotions, and the effects on memory in the two studies were compared. The emotions induced by the feedback resulted in positive emotions having the strongest effects on memory, while negative emotions had the weakest memory effect. However, when the emotional materials were used, there were different outcomes: negative emotional memories were the best, and neutral memories were the worst. Based on these results, we may conclude that different emotion-inducing methods have different effects on memory and that emotionally enhanced memory is not applicable to all emotion-inducing modes.

Introduction

Emotion has a great influence on cognitive processes, and the effects of emotion on memory have been of interest to many researchers (Bell, Mieth, & Buchner, 2015; Flores & Berenbaum, 2017). Emotional information is more likely to be remembered than neutral information, and this is called emotionally enhanced memory (EEM).

Numerous studies have suggested that emotional information enhances memory at all stages of memory (Talmi & Moscovitch, 2004; Chapman et al., 2012; de Voogd, Fernández, & Hermans, 2016). In general, when emotional information is encoded, it undergoes more consolidation and fine processing than neutral information (Sharot & Phelps, 2004; Palomba, Angrilli, & Mini, 1997). Thus, it can be more accurately retrieved and extracted (Buchanan, 2007). For example, in the study by Kensinger and Schacter (2008), positive, negative, and neutral images were used as experimental materials to explore the effects of emotional valence on memory. Functional magnetic resonance imaging (fMRI) technology was used to analyze neural mechanisms. The results showed that both positive and negative images caused a stable enhancing effect on emotional memory. Moreover, brain imaging results showed that successfully encoded positive and negative stimuli both activated the amygdala and the orbitofrontal cortex. In the negative stimulation conditions, the degree of activation in the right fusiform gyrus was greater, and the degree of activation in the left prefrontal lobe and parietal lobe was greater in the positive stimulation conditions. The authors believed that the results indicated that negative stimuli enhance detailed processing at the perceptual level, while positive stimuli enhance conceptual and semantic processing. However, some studies have found that the effect of EEM only exists in the memory performance related to negative stimuli or has less effect with positive stimuli (Kensinger, 2007; Choi, Kensinger, & Rajaram, 2013).

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The studies mentioned above all used emotional materials as tools to induce particular emotional responses. However, similar to emotional materials, emotional events can also be used as an induction method. For example, emotional music, movies, and feedback have been used to induce emotions to explore their effects on memory (Gasper & Clore, 2002; Mather & Sutherland, 2011). Tambini, Rimmele, Phelps, & Davachi (2016) found that 9–33 min after exposure to emotionally aroused stimuli, participants' brains continued to immerse themselves in the emotional state, which affected the subsequent encoding of neutral stimuli.

It is uncertain whether emotional events would have a similar impact on memory to emotional materials. In general, negative stimuli lead to better memory performance than neutral stimuli, while positive stimuli are better or equally well remembered as neutral stimuli. However, the emotions induced by emotional events caused the opposite effects on memories. For example, Mather & Schoeke (2011) found that picture memory was better after positive feedback than after negative feedback. During the coding process, the participants were first presented with a cue about whether the required response would result in gains, losses, or no changes. The participants were then asked to judge whether the picture was positive or negative and finally received feedback. During the test phase, the participants were asked to recall and recognize pictures. During recall and recognition, the results in the gain condition were better than those obtained in the loss condition. Adcock et al. (2006) found that rewards lead to activation of the reward system, which can enhance memory. Similar results have been found in other studies (Wittmann, Schiltz, Boehler, & Düzel, 2008; Wittmann et al., 2005).

The studies mentioned above suggest that the effects of these two emotion-evoking methods on memory may be completely different; thus, the effects of EEM may not be applicable in all cases. Therefore, exploring the effects of different emotion-evoking methods on memory is of great significance for improving relevant theories of emotional memory. Moreover, the aforementioned studies usually used different experimental paradigms; therefore, it is difficult to compare the effects of the two induction methods on memory. In this study, similar experimental paradigms were used to compare the effects of two emotion-evoking methods on memory. In the study by Bowen and Spaniol (2017), rewards were used to induce motivation and emotion. Bowen believed that the rewards obtained by the participants through effort induce motivation and that random rewards induce emotions. Therefore, the present study used random rewards to induce the participants' emotions. In Experiment 1, we used the feedback results from a guessing task as an emotional event, and the feedback results were linked to a neutral face to form different emotional conditions. In Experiment 2, emotional faces with different valence were used as emotional materials to induce emotions, and we subsequently compared whether those two emotion-inducing methods had different effects on face memory.

Experiment 1 effects of feedback results on memory

Methods

Participants

We used an effect size of $\eta_p^2 = 0.25$ to conduct a power analysis with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009), which suggested that at least 60 participants were required for 90% power to detect the effect given an α level of 0.05. Consequently, 72 participants with normal or corrected vision participated in the experiment (39 females, aged 20.03 ± 1.84 year). After completing the experiment, the participants were given ¥15 as a reward. None of participants participated in both experiments.

Stimuli

A total of 160 neutral faces, of which 80 were male faces and 80 were female faces, from the Chinese Facial Affective Picture System (Gong, Huang, Wang, & Luo, 2011) were selected. All facial pictures in the system were obtained by 60 participants who rated their valences and arousal at 9 points. The pixel size of the faces was 260 × 300. To investigate the faces correlated to the positive, negative, and neutral feedback manipulations during the learning phase, we randomly allocated 160 neutral faces into four groups: three as old faces related to positive, negative, and neutral feedback conditions during the learning phase and the remaining one group as new faces mixed with those old faces and displayed during the memory test phase. There were 40 faces in each group, including half male and half female. In the learning phase, the faces were randomly presented in pairs (same gender in each pair), and the two faces were 20 cm horizontally aligned with the fixation. In the test phase, three groups of old faces and one group of new faces were randomly and individually presented. The ratio of old-to-new faces was 3:1. Analyses on valence and arousal ratings show that the 4 groups of faces did not systematically differ from each other.

A one-way ANOVA (condition: positive, negative, neutral, new) was performed on the valences. The main effect of condition was not significant [$F(3,156) = 0.789$, $p = 0.502$; positive: 4.313 ± 0.586; negative: 4.174 ± 0.524; neutral: 4.222 ± 0.472; new: 4.320 ± 0.425]. One-way ANOVA of arousal (condition: positive, negative, neutral, new) showed that the main effect of face type was not significant [$F(3,156) = 1.252$, $p = 0.293$; positive: 3.609 ± 0.512;

negative: 3.816 ± 0.632; neutral: 3.841 ± 0.717; new: 3.875 ± 0.815].

Procedures

The experimental procedure was programmed with Presentation software. The participant sat on a chair in a soundproof room to complete the experiment. The background of the monitor was black and 80 cm away from the participant.

Learning phase: Two faces were presented horizontally and on the left and right side of the central focus point on the screen for 800 ms, and the participants were required to judge the identity (deceiver or trustworthy) of the faces according to their subjective feelings. To avoid the deceiver effect (Buchner, Bell, Mehl, & Musch, 2009), half of the participants were asked to guess which face was the deceiver, and the remaining participants needed to guess which face was trustworthy in each trial. If participants selected the left face, they pressed the F key. If participants selected the right face, they pressed the J key. The feedback results were given after the keyboard was pressed. Then, the next pair of faces was presented at an interval of 1400–1800 ms. In the instructions, the participants were told the following: "There are two situations in which the face pairs are presented. One case is that one of the two faces is trustworthy, and another is a deceiver; in the other case, both are trustworthy faces. In the first case, when the judgment is correct, the word 'correct' will be presented in the feedback phase, while an error in judgment will be followed by the word 'error' in the feedback phase. In the second case, the word 'draw' will be presented in the feedback phase. The participants had 100 points at the beginning. When they made a correct judgment, they could obtain one point; if they made an incorrect judgment, one point would be deducted; and nothing would change in the score if a 'draw' occurred. The reward was calculated based on the final score." To ensure a sufficient number of faces in each group, each pair of faces was included in the fixed feedback group. Namely, in the positive group, the face feedback results were "correct", the feedback results in the negative group were "wrong", and the feedback results of the neutral group were "draw", regardless of the actual answer.

Test phase: A single face was presented in the center of the screen, and the participants were instructed to judge whether the face was displayed in the learning phase. The face remained present until the response was made by the participants. After that, the next face was presented at an interval of 1400–1800 ms.

Analysis

The analysis was performed using SPSS 24.0. A measure of old/new discrimination (Pr) was computed: Pr = p (hit) − p (false alarm) based on the work by Snodgrass and Corwin (1988). The reaction time represented the average response time in trials with correct responses.

A mixed-design ANOVA with a within-participants factor with 3 levels (feedback type: positive, negative, neutral) and a between-participants factor with two levels (gender: male, female). The least significant difference (LSD) was used for post hoc comparisons.

Results

The results of Pr values showed that the main effect of feedback type was significant [$F(2,140) = 8.695$, $p < 0.001$, $\eta_p^2 = 0.110$, power = 0.967]. The post hoc tests showed that the Pr value for positive feedback was greater than that for negative feedback [$p < 0.001$, 95% CI (0.025, 0.070)], the Pr value for positive feedback was greater than that for neutral feedback [$p = 0.041$, 95% CI (0.001, 0.047)], and the Pr value for negative feedback was less than that for neutral feedback [$p = 0.045$, 95% CI (− 0.046, − 0.001)]. The main effect of gender and the interaction between valence and gender were not significant (see Fig. 1a and Table 1).

The results of RTs showed that all the main effects and the interaction effect were not significant. (see Fig. 1b and Table 1).

Fig. 1 Pr and mean RT in Experiment 1. Pr = p (hit) − p (false alarm). Error bars represent standard errors

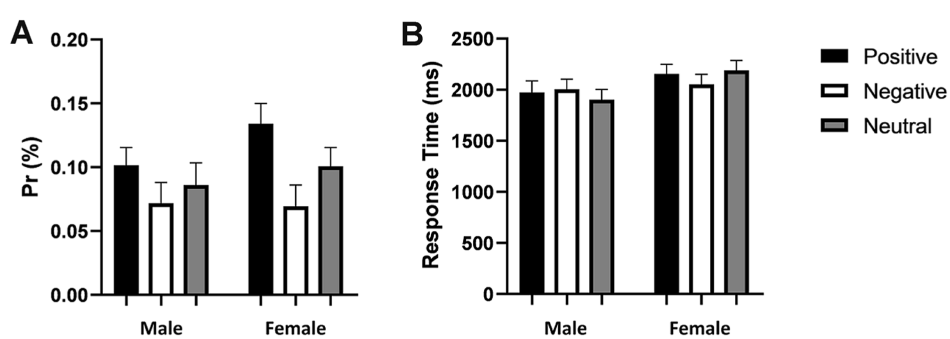

Table 1 Results of Experiment 1

	F	p	η_p^2
Pr values			
Feedback type	8.695	< 0.001	0.110
Gender	0.659	0.420	0.009
Feedback type × gender	1.267	0.285	0.018
RT			
Feedback type	0.234	0.791	0.003
Gender	1.804	0.184	0.025
Feedback type × gender	2.445	0.090	0.034

Discussion

The experimental results showed that in the recognition task, memory in the negative conditions was the worst, and memory in the positive conditions was the best. This difference existed both in male and female participants. There were no significant differences among the RTs in each condition.

The results of this experiment are consistent with the results of many studies (Mather & Schoeke, 2011); Wittmann et al., 2005, 2008; Blanchette et al., 2016) that have shown that memory performance under positive feedback conditions is significantly greater than that under negative feedback conditions. In the experiment by Wittmann et al. (2005), reward-predicting pictures had a better memory effect than non-reward-predicting pictures, and fMRI results showed that the reward-predicting pictures induced higher activation in the hippocampus and the midbrain. These results suggested that the activation of dopaminergic midbrain regions enhances hippocampus-dependent memory formation, possibly by enhancing consolidation. The significance of this neural mechanism is that when an individual does something that can be rewarded, remembering this outcome will be helpful to obtain the reward again after repeating the action later. However, when previous researchers studied the effect of feedback on memory, they usually compared the differences between positive and negative feedback on memory. This kind of design cannot well distinguish whether positive feedback enhances memory or negative feedback inhibits memory. The results of the present experiment indicate that the enhancement effect of positive feedback and the inhibition effect of negative feedback coexist. There are two possible explanations for this result. One is that the difference between positive and neutral feedback and the difference between neutral and negative feedback are both caused by the reward effect. Under this circumstance, neutral feedback is more positive than negative feedback, which leads to stronger of the reward effect relative to negative conditions. Another possibility is that under the condition of negative feedback, the participants suppressed the extraction of face stimuli bound to negative feedback to avoid the harm of negative emotions. Blanchette et al. (2016) used baboons as participants and found that negative conditions had a slower memory speed and lower accuracy than neutral conditions. Blanchette attributed this to a cognitive avoidance pattern of negative stimuli in the baboon's memory process. This mode is helpful to avoid harm from the negative stimulus to the individual.

Results of Experiment 1 showed that the effects of feedback on memory. In the Experiment 2, we would further investigate the effects of emotional expressions on memory.

Experiment 2 effects of emotional expressions on memory

Methods

Participants

A total of 66 participants with normal or corrected vision participated in the experiment (35 females, aged 19.97 ± 1.86 year). After completing the experiment, the participants were given ¥ 15 as a reward. None of them had participated in Experiment 1.

Stimuli

Eighty negative faces, 80 neutral faces, and 80 positive faces from the Chinese Facial Affective Picture System were selected, of which half were male and half female. The emotional faces were randomly assigned to old (60 faces) and new (20 faces) conditions, of which half were male and half female. The experiment was divided into two phases: the learning phase and the testing phase. In the learning phase, the faces were randomly presented in pairs (same gender and same emotional expression in each pair). In the test phase, three groups of old faces and one group of new faces were randomly and individually presented. The ratio of old-to-new faces was 3:1.

A two-way ANOVA with 3 (valence: positive, negative, neutral) × 2 (face type: new and old) factors revealed that the main effect of valence was significant [$F(2,234) = 291.425$, $p < 0.001$]; the main effect of face type was not significant [$F(1,234) = 0.581$, $p = 0.447$]; and the interaction effect was not significant [$F(2,234) = 0.850$, $p = 0.429$, negative old: 2.855 ± 0.469; negative new: 3.042 ± 0.664; neutral old: 4.267 ± 0.557; neutral new: 4.171 ± 0.563; positive old: 5.629 ± 0.814; positive new: 5.752 ± 0.561].

A two-way ANOVA with 3 (valence: positive, negative, neutral) × 2 (face type: new and old) factors for arousal was performed and revealed that the main effect of valence was significant [$F(2,234) = 86.915$, $p < 0.001$]; the main effect of face type was not significant [$F(1,234) = 0.427$,

$p = 0.514$]; and the interaction effect was not significant [$F(2,234) = 0.166$, $p = 0.847$] (negative old: 6.089 ± 1.256; negative new: 6.300 ± 1.059; neutral old: 3.689 ± 0.532; neutral new: 3.783 ± 0.720; positive old: 4.705 ± 1.176; positive new: 4.701 ± 1.154).

Procedures

The experimental procedure was programmed using Presentation software. The participants sat in a seat in a soundproof room to complete the experiment. The background of the monitor was black and 80 cm away from the participant.

Learning stage: no feedback was provided after the button was pressed, and the remaining details were the same as in experiment 1.

Test phase: A single face was presented in the center of the screen, and the subject was instructed to judge whether the face had just appeared during the learning phase. The face was presented until a response was made by the participants. After that, the next face was presented at an interval of 1400–1800 ms.

Analysis

The new faces in the test phase of experiment 1 were all neutral faces. Under the three conditions, the false alarm rate was the same; therefore, there was no difference in the false alarm rate among the conditions. In contrast to experiment 1, the new faces of the three conditions in experiment 2 represented three kinds of emotional faces, and the false alarm rates in the three conditions may have been different. Therefore, in experiment 2, not only the Pr value and the reaction time but also the hit rate and the false alarm rate were analyzed.

Mixed-design ANOVAs of the new and old recognized Pr values, hit rate, false alarm rate and RTs was performed with 3 (feedback type: positive, negative, neutral) × 2 (gender: male, female) factors. Gender was a between-participants factor. The LSD was used for post hoc comparisons.

Results

The results of the Pr values showed that the main effect of valence was significant [$F(2,128) = 130.879$, $p < 0.001$, $\eta_p^2 = 0.672$, power = 1.000]. A post hoc test revealed that the Pr value for negative faces was significantly greater than that for positive faces [$p < 0.001$, 95% CI (− 0.307, − 0.223)]; the Pr value for positive faces was greater than that for neutral faces [$p = 0.002$, 95% CI (0.025, 0.106)]; and the Pr value for negative faces was significantly greater than that for neutral faces [$p < 0.001$, 95% CI (0.284, 0.377)]. The main effect of gender and the interaction effect were not significant (see Fig. 2a and Table 2).

In terms of the hit rate, the main effect of valence was significant [$F(2,128) = 24.425$, $p < 0.001$, $\eta_p^2 = 0.276$, power = 1.000]. The post hoc tests revealed that the hit

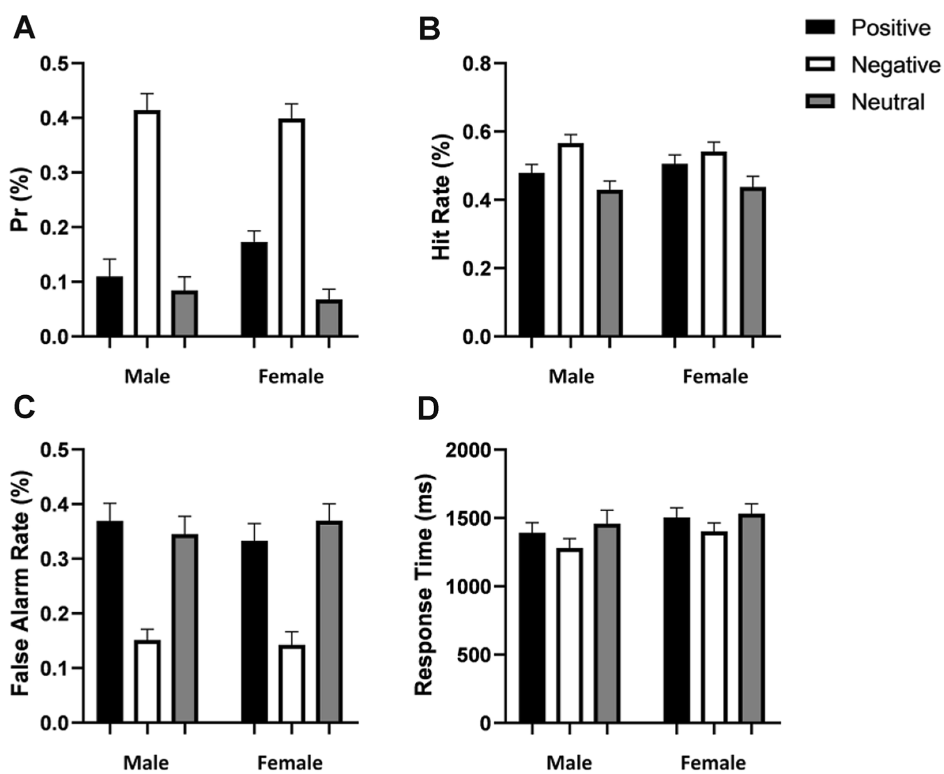

Fig. 2 Pr, hit rate, false alarm rate and mean RT in Experiment 2. Pr = p (hit) − p (false alarm). Error bars represent standard errors

Table 2 Results of Experiment 2

	F	P	η_p^2
Pr values			
Feedback type	130. 879	< 0.001	0.672
Gender	0.151	0.699	0.002
Feedback type × gender	2.310	0.105	0.035
Hit rate			
Feedback type	24.425	< 0.001	0.276
Gender	0.041	0.840	0.001
Feedback type × gender	0.009	0.923	0.000
False alarm rate			
Feedback type	70.316	< 0.001	0.524
Gender	0.041	0.840	0.001
Feedback type × gender	1.159	0.317	0.018
RT			
Feedback type	12.515	< 0.001	0.164
Gender	1.064	0.306	0.016
Feedback type × gender	0.336	0.715	0.005

rate for negative faces was significantly higher than that for positive ones ($p < 0.001$); the hit rate for negative faces was also significantly higher than that for neutral faces ($p < 0.001$); and the hit rate for neutral faces was also significantly higher than that for positive faces ($p < 0.001$). The main effect of gender and the interaction effect were not significant. In terms of the false alarm rate, the main effect of valence was significant [$F(2,128) = 70.316$, $p < 0.001$, $\eta_p^2 = 0.524$, power = 1.000]. The post hoc tests revealed that the false alarm rate for negative faces was significantly lower than that for positive faces [$p < 0.001$, 95% CI (0.164, 0.244)] and that the false alarm rate for negative faces was also significantly lower than that for neutral faces [$p < 0.001$, 95% CI (− 0.244, − 0.164)]. The difference between the positive and neutral valences was not significant [$p = 0.735$, 95% CI (− 0.045, 0.032)]. The main effect of gender and the interaction effects were not significant (see Fig. 2b and Table 2).

The results of RTs showed that the main effect of valence was significant [$F(2,128) = 12.515$, $p < 0.001$, $\eta_p^2 = 0.164$, power = 0.996]. Post hoc tests revealed that the RT in response to negative faces was significantly shorter than that with positive faces [$p < 0.001$, 95% CI (51.399, 163.287)], and the RT in response to negative faces was also significantly shorter than that in response to neutral faces [$p < 0.001$, 95% CI (− 221.878, − 86.353)]. The difference between the positive and neutral faces was not significant [$p = 0.155$, 95% CI (− 111.770, 18.225)]. The main effect of gender and the interaction effect between gender and valence were not significant. (see Fig. 2c and Table 2).

Discussion

The results of experiment 2 were consistent with those of previous studies. Memory was the best under negative valence conditions, followed by positive valence conditions, and the worst memory performance was found under neutral valence conditions, indicating that the emotional materials effectively contributed to EEM. In addition, we also found that negative emotions were associated with the lowest false alarm rates, but there was no significant difference between positive and neutral emotions. In a previous study of false memory, positive emotions led to increased false memory (Forgas, Laham, & Vargas, 2005; Levine & Bluck, 2004). Some studies have found no difference in memory performance between neutral and positive valence information, but the participants had higher confidence in the memories for the positive information (Kensinger & Schacter, 2006). Kensinger (2007) argued that this was because negative emotions process information in an analytical and detailed manner, while positive emotions rely on a wider range of schematic or thematic information and ignore the details. Therefore, under positive emotional conditions, participants were likely to judge similar memory items as old.

It can also be seen from the RTs that since the negative emotions processed the information in a detailed processing manner, the participants judged the memory items relatively quickly. Positive emotions did not have this advantage in the RT due to a lack of detailed processing.

General discussion

The present study compared the effects of two emotion-inducing methods on face memory using two experiments. The study found that the two emotionally induced patterns had completely different effects on the face memory performance. The experiment using feedback as an induction method revealed the best memory for neutral faces with positive feedback and the worst memory for neutral faces with negative feedback. When emotional materials were used as a mode of induction, the negative condition was associated with the best memory, and the worst memory was observed in the neutral condition.

There are two possible explanations for this difference. First, the cognitive processing was different. The emotions induced by feedback were bound to memory items by the experimental task during the learning stage. In the test phase, the retrieval of memory items also caused the recall of emotional events tied to the memory items. Therefore, under the condition of positive feedback, positive emotions enhanced the ability to remember to repeat rewarding behaviors. Under negative feedback conditions, the cognitive avoidance mode of negative events during the retrieval phase avoided the harm of negative emotions. Therefore, memory performance was better in the positive feedback condition but worse in the negative feedback condition, relative to the neutral feedback condition. In contrast to the feedback manipulation, the emotions evoked by emotional stimuli were generated by the memory material itself, and the recall of negative stimuli during the retrieval phase could not be avoided. In addition, negative stimuli narrowed attention and allowed the participants to memorize details well, thus enhancing memory (Gasper & Clore, 2002; Gable & Harmon-Jones, 2010). Moreover, the mechanism of the better memory effect of negative stimuli also has certain survival significance (Miller, 2004). Therefore, memory was better under negative stimulation. The results of positive stimuli were similar to those of positive feedback and led to better memory performance.

Second, the mood types induced by the two modes were different. Barrett et al. (2007) suggested that although emotions can be simply divided into two core affects, namely happy and unpleasant, the core affect is not, in and of itself, sufficient for the mental representation of emotion. There is still much to be learned about the additional content that constitutes mental representations of emotion. The emotional experience caused by the failure of decision-making in experiment 1 was a regretful emotion. Regret results when the outcome of a decision is compared with a better outcome from among the rejected alternatives (Mellers, Schwartz, & Ritov, 1999) and is regulated by a cognitive process called counterfactual thinking (Camille et al., 2004; Coricelli et al., 2005). In other words, it is the thought "If only I chose another option". The regretful emotion in experiment 1 was different from the emotion that was directly triggered by the emotional stimuli in experiment 2. The regretful emotion was essentially a complex cognitive-based emotion (Coricelli, Dolan, & Sirigu, 2007). Previous studies have shown that different emotional types have different effects on memory even if they are all negative emotions (Charash & McKay, 2002; Croucher et al., 2011; Chapman et al., 2012; Xiang et al., 2017), making it possible that different types of emotions can lead to different memory scores.

The results of the present study show that the effect of feedback from the emotional context on memory is different from the effect of emotion induced by emotional material itself. EEM cannot be widely applied to all emotional memories. Negative emotions may not enhance memory during some induction tasks but may damage memory. Previous research on emotion and memory has focused more on the use of the material's own emotional state. Paying more attention to the effects of different evoking methods on memory and using cognitive neural technology to understand the mechanisms in the brain will help improve relevant theories of emotional memory. Furthermore, such studies will be conducive to the development of research in areas related to emotional memory, such as emotional disorders.

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