Emotion Regulation Facilitates Forgetting of Negative Social Feedback: Behavioral and EEG Evidence

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Abstract

Peer rejection, interpersonal rejection, and other forms of negative social feedback can induce social pain. Negative social feedback that is difficult to forget may cause persistent psychological distress, thereby impairing mental health. The present study employed a social evaluation paradigm, combined with EEG data, to investigate the potential benefits of emotion regulation on emotional responses and memory for negative social feedback, as well as the underlying cognitive neural mechanisms. Participants were placed in a peer evaluation scenario where they viewed negative social feedback about themselves from others to elicit social pain, thereby examining how emotion regulation (cognitive reappraisal and distraction) alleviates social pain and whether it facilitates forgetting of negative feedback memories. The study also investigated how depressive symptoms influence the efficiency of emotion regulation. The results demonstrated that both cognitive reappraisal and distraction effectively reduced participants' experience of social pain and promoted forgetting of negative social feedback in both the short and long term. When examining how depressive symptoms affect EEG activity during emotion regulation, we found that the amplitude of the late positive potential (LPP) in the centroparietal region was negatively correlated with depression scores when using the distraction strategy. Further multivariate pattern analysis of whole-brain potential activities for the two emotion regulation strategies revealed that participants with high versus low depressive symptoms exhibited different neural decoding efficiencies during emotion regulation, particularly that the whole-brain activity patterns of high depressive symptom participants when employing the distraction strategy were significantly distinct from those when using the watch strategy. Integrating behavioral and EEG findings, this study provides evidence for the beneficial effects of both cognitive reappraisal and distraction strategies on social emotion and memory, and suggests that distraction may be a more effective regulation strategy at higher levels of depression.

Full Text

Emotion Regulation Promotes Forgetting of Negative Social Feedback: Behavioral and EEG Evidence

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Abstract

Negative social feedback, such as peer rejection and interpersonal criticism, induces social pain. When such painful experiences become difficult to forget, they can cause persistent psychological distress and impair mental health. Using a social evaluation paradigm combined with EEG recordings, this study investigated the potential benefits of emotion regulation on emotional responses to and memory for negative social feedback, as well as the underlying cognitive and neural mechanisms. Participants experienced social pain by viewing negative social feedback from peers, and we examined how emotion regulation (cognitive reappraisal and distraction) alleviated this social pain and whether it facilitated forgetting of the negative feedback. We also investigated how depressive symptoms influenced the efficiency of emotion regulation. The results demonstrated that both cognitive reappraisal and distraction effectively reduced social pain and promoted forgetting of negative social feedback in both the short and long term. When examining how depressive symptoms affected the EEG correlates of emotion regulation, we found that the amplitude of the central-parietal late positive potential (LPP) during distraction was negatively correlated with depression scores. Furthermore, multivariate pattern analysis of whole-brain electrical activity during emotion regulation revealed that individuals with high versus low depressive symptoms showed different neural decoding efficiencies, particularly when using distraction. Specifically, high-depression participants exhibited significantly different whole-brain activity patterns between distraction and passive viewing conditions. Together, the behavioral and EEG findings demonstrate the beneficial effects of both reappraisal and distraction on social emotion and memory, and suggest that distraction may be a more effective regulation strategy at higher depression levels.

Keywords: social feedback, emotion regulation, motivated forgetting, depression, EEG
Classification Code: B842

In daily social interactions, we constantly encounter evaluations from others regarding our personality and behavior. Such evaluative information from interpersonal interactions constitutes social feedback (Rappaport & Barch, 2020). Specifically, criticism or praise from others, their evaluations, preferences, and willingness to interact, as well as likes and comments we receive on social media, are all common forms of social feedback. Appropriate processing of social feedback plays a crucial role in maintaining and promoting harmonious interpersonal relationships. For instance, we need to adjust our attitudes and behaviors based on the information conveyed by social feedback to effectively sustain relationships with family members, friends, and colleagues. As important social information, social feedback significantly impacts our emotions (Eisenberger & Lieberman, 2004). When we experience peer rejection or receive negative interpersonal evaluations, such negative social feedback threatens our social relationships and causes distress and suffering. The resulting negative emotional response is referred to as "social pain"(Eisenberger, 2012). However, dwelling on and being unable to forget negative social feedback (e.g., through rumination) can lead to persistent psychological stress and increase the risk of psychiatric disorders (Kashdan & Roberts, 2007; Stone et al., 2016). In today's internet era, interpersonal communication has become more diverse and frequent, increasing the probability of receiving negative social feedback (e.g., malicious comments from strangers, cyberbullying). Therefore, how to effectively regulate the negative emotional responses and memories elicited by negative social feedback to protect mental health has become an urgent and important scientific question.

When facing negative life events, people often actively employ various strategies to regulate their emotions and cognition. For example, individuals can alleviate negative emotions by changing their perspectives, viewpoints, or attitudes toward an event and reinterpreting it. This strategy, which focuses on modifying cognitive appraisal, is called "cognitive reappraisal" (Gross, 1998a). Numerous studies have demonstrated that reappraisal significantly improves negative emotions, and this strategy constitutes a core component of many clinical psychotherapies, particularly cognitive-behavioral therapy (Beck, 2005; Clark, 2022; Wolgast et al., 2011). In addition to reappraisal, distraction is also a commonly used and effective emotion regulation strategy in daily life, showing unique advantages especially in high-intensity negative situations (Matthews et al., 2021; Sheppes et al., 2011). Can these two strategies also effectively regulate negative emotions elicited by social feedback? Recent studies have found that both reappraisal and distraction can effectively reduce negative emotional responses to social feedback and help alleviate social pain (He et al., 2020; Li et al., 2022; Nasso et al., 2020; Zhao et al., 2021). However, beyond reducing negative emotional responses, does emotion regulation also help people forget negative social feedback?

The interplay between emotion and memory represents one of the most extensively studied topics in psychology and neuroscience (Dolan, 2002; Kensinger & Ford, 2020; LeDoux, 1994; Phelps, 2006). A large body of research indicates that emotional stimuli enhance memory encoding and retrieval processes compared to neutral stimuli, leading to emotional memory enhancement (LaBar & Cabeza, 2006; Talmi, 2013). Conversely, retrieving emotional memories can influence current emotional experiences and cognitive functions (Engen et al., 2017; Williams et al., 2022). Particularly after traumatic experiences, intrusive memories and rumination can cause attention deficits, cognitive decline, low mood, high arousal, and contribute to psychiatric disorders such as depression, anxiety, and post-traumatic stress disorder (Costanzi et al., 2021; Hu et al., 2017; Stramaccia et al., 2021). Therefore, effective control over traumatic negative emotional memories can protect cognitive function and emotional health (Engen & Anderson, 2018; Nørby, 2018). However, previous research has primarily focused on how top-down inhibitory functions control memory and promote forgetting (Anderson & Hanslmayr, 2014; Anderson & Hulbert, 2021), with few studies examining how emotion regulation might help people forget negative social memories. We propose that investigating forgetting of negative social memories from the novel perspective of emotion regulation can not only enrich theoretical models of emotion-memory interactions but also provide valuable clinical insights.

Previous studies have preliminarily explored how emotion regulation, particularly expression suppression and cognitive reappraisal, influences emotional memory. Consistently, expression suppression reduces recall accuracy for emotional materials, suggesting that monitoring and suppressing emotional expression impairs encoding of emotional stimuli, thereby leading to subsequent memory decline (Binder et al., 2012; Dillon et al., 2007; Katsumi & Dolcos, 2020; Richards & Gross, 2000). However, the effects of cognitive reappraisal on emotional memory remain controversial (Davis & Levine, 2013; Egloff et al., 2006; Hayes et al., 2010; Richards et al., 2003; Richards & Gross, 2000; Sheppes & Meiran, 2008). In addition to expression suppression and reappraisal, early studies have also found that using distraction reduces memory for emotional materials (Richards & Gross, 2006; Sheppes & Meiran, 2008). Although these studies have accumulated evidence on how emotion regulation affects memory, most have used non-social, low self-relevant emotional pictures, such as frightening snakes or natural disasters, primarily drawn from the International Affective Picture System (IAPS; Lang et al., 2008). These stimuli have limited ecological validity, which may constrain participants' motivation and effectiveness in emotion regulation (Nasso et al., 2020; Nelson et al., 2015). In contrast, negative emotions elicited by social feedback are characterized by high self-relevance, which may enhance participants' motivation and effectiveness in emotion regulation (Nasso et al., 2020). Due to heterogeneity in materials and tasks, findings from studies using emotional pictures cannot be simply generalized to research on emotion regulation and memory for negative social feedback. Therefore, investigating how emotion regulation influences emotional responses to and memory for social feedback can not only enhance ecological validity and generalizability but also further enrich theoretical models of emotion and memory regulation from the perspective of social memory processing.

Combining recently developed social feedback research frameworks with emotion regulation experimental paradigms (Li et al., 2022; Nasso et al., 2020), the present study aimed to examine how emotion regulation influences emotions and memory for negative social feedback. Although three common emotion regulation strategies—cognitive reappraisal, distraction, and expression suppression—may all influence memory, expression suppression is generally considered a maladaptive strategy (Aldao & Nolen-Hoeksema, 2010; Schäfer et al., 2017) with negative effects on emotion, cognition, and behavior (Brockman et al., 2017; Butler et al., 2007; Gross, 2002). In contrast, the use of reappraisal and distraction in daily life predicts increased positive emotions (Boemo et al., 2022). Based on these considerations, this study focused on the two adaptive emotion regulation strategies of cognitive reappraisal and distraction. In addition to memory for negative social feedback, we also examined how emotion regulation influences participants' evaluations of the feedback providers and themselves. Previous research has shown that social memory influences our social attitudes and decisions toward others (FeldmanHall et al., 2021; Schaper et al., 2019), and forgetting negative social feedback can lead to more positive evaluations of feedback providers (Xie et al., 2021). Therefore, changes in participants' evaluations of others and themselves following emotion regulation can be considered implicit effects of emotion regulation. Given the close relationship between emotion and memory, we hypothesized that emotion regulation of negative social feedback would not only reduce negative emotional responses but also facilitate forgetting of negative social feedback, which in turn would improve evaluations of feedback providers and the self.

Another aim of this study was to examine whether depressive symptoms influence the effectiveness of emotion regulation for negative social feedback. Increasing evidence suggests that individuals with depression exhibit deficits in processing social feedback (Rappaport & Barch, 2020; Reinhard et al., 2020), including reduced anticipation of and anhedonia for positive social feedback (Caouette & Guyer, 2016; Davey et al., 2011; He et al., 2019; Zhang et al., 2020), as well as heightened sensitivity to negative social feedback leading to enhanced and prolonged social pain (Hsu et al., 2015; Jankowski et al., 2018; Kumar et al., 2017; Silk et al., 2014). These processing deficits are closely associated with various social impairments and maladaptive behaviors in depressed individuals (Hames et al., 2013; Pulcu & Elliott, 2015). Regarding memory, healthy individuals typically show spontaneous forgetting of self-threatening information (e.g., negative social feedback, personal failures; Rigney et al., 2021; Sedikides et al., 2016; Yao et al., 2021), whereas depressed individuals exhibit memory biases for negative self-relevant information (Gaddy & Ingram, 2014; Houle-Johnson et al., 2019; Saunders, 2011; Xie et al., 2022). Given these deficits in processing negative social information in depression, investigating how emotion regulation can improve emotion and memory has important clinical implications. Therefore, this study measured participants' depression levels and examined the relationships among depressive symptoms, emotion regulation effectiveness, and post-test memory performance. Finally, to provide multimodal evidence for how emotion regulation influences processing of negative social feedback, we used both self-reported emotional experience as a subjective index of regulation effectiveness and examined the late positive potential (LPP) in event-related potentials (ERPs) as a neural index (Li et al., 2022; Myruski et al., 2019). In addition to traditional univariate ERP analysis, we employed machine learning methods to conduct multivariate pattern analysis (MVPA) on whole-brain EEG activity during the emotion regulation task to distinguish brain activity patterns across different regulation strategies and examine how depressive symptoms influence these neural patterns. Compared to conventional univariate ERP analysis, MVPA offers higher sensitivity and specificity in examining similarities and differences in whole-brain neural activity patterns across emotion regulation conditions by utilizing multi-channel and multi-timepoint EEG data (Carlson et al., 2019; Hebart & Baker, 2018).

2.1 Participants

Sixty-eight university students were recruited for this study. All participants met the following inclusion criteria: right-handed; no recent illness or medication use; no history of neurological or psychiatric disorders; normal or corrected-to-normal vision. The study protocol was approved by the University of Hong Kong Ethics Committee. All participants provided informed consent prior to the experiment and received monetary compensation upon completion. After signing the informed consent form, participants' depressive symptoms were assessed using the Chinese version of the Beck Depression Inventory-Second Edition (BDI-II; Jiang & Yang, 2020). Depression scores in this sample ranged from 0 to 42.

Due to non-compliance with task instructions during the emotion regulation task (see Section 2.3.3 for details), data from two participants were excluded from the sample. Additionally, EEG data were not recorded for seven participants due to equipment failure, and data from another 14 participants were excluded from EEG analysis due to poor data quality (fewer than 60% of trials remained valid after preprocessing). Consequently, the final sample for behavioral data analysis comprised 66 participants (16 males) with a mean age of 20.6 ± 1.9 years. The final sample for EEG data analysis comprised 45 participants (10 males) with a mean age of 20.9 ± 1.9 years.

The experimental paradigm used in this study was adapted from a recently published study by Nasso et al. (2020), and we therefore adopted a similar sample size (N = 61).

2.2 Experimental Design and Materials

This experiment employed a single-factor four-level within-subjects design. Based on the emotional valence of materials and emotion regulation instructions, the four within-subjects conditions were: negative watch, negative reappraisal, negative distraction, and positive watch. According to previous literature (Nasso et al., 2020), the positive watch condition was included only to increase the credibility of the experimental cover story and to verify the effectiveness of the valence manipulation (i.e., to confirm that positive and negative social feedback elicited corresponding emotional responses). As the present study focused primarily on emotion regulation of negative social feedback, results from the positive watch condition are reported for descriptive purposes only and were not included in the main analyses.

The experimental materials consisted of peer ID photos used for the peer evaluation task and personality adjectives serving as social feedback. The study used 50 standardized ID photos (25 male, 25 female) selected from a previously established stimulus database (Xie et al., 2021; 2022). Ten photos were used during the preparation phase and practice trials of the emotion regulation task, while the remaining 40 photos were used in the formal experiment.

The other set of materials comprised 60 personality adjectives, including 40 negative and 20 positive adjectives selected from the Chinese Affective Words System (Wang et al., 2008). Ten negative and ten positive adjectives were used during the preparation phase and practice trials, leaving 30 negative and 10 positive adjectives for the formal experiment.

The materials for the formal experiment were combined into 40 photo-word pairings, distributed across the four within-subjects conditions with 10 pairings per condition. Material properties (gender and facial attractiveness of the individuals in the photos, as well as emotional valence and arousal of the adjectives) were balanced across conditions, and assignment of materials to the three negative conditions was counterbalanced across participants.

2.3 Experimental Procedure

The experimental procedure consisted of five phases: preparation, baseline task, emotion regulation (with EEG recording), immediate post-test, and delayed post-test (Figure 1A). The experimental program was developed and run using E-Prime 2.0 (Psychology Software Tools, Inc., Sharpsburg, PA).

2.3.1 Preparation Phase

When participants signed up for the experiment, they were asked to provide a digital ID photo and were informed that the study concerned "first impression evaluation" (Somerville et al., 2006). They were told their photo would be used as experimental material and would be viewed and evaluated by peer university students from other institutions. On the experimental day, participants learned that the peer evaluation method involved choosing between two opposite personality adjectives (e.g., modest vs. arrogant) that best described the participant' s character (Nasso et al., 2020). To increase the credibility of the cover story, participants first viewed 10 ID photos of unfamiliar peers and selected which of two adjectives better matched each stranger' s personality based on first impressions.

2.3.2 Baseline Task Phase

This phase included two tasks: rating likability of peers and rating self-descriptiveness of personality adjectives.

Peer Likability Rating: Participants sat in front of a computer screen and viewed 40 ID photos in random order, rating the likability of each person on a 9-point scale (1 = extremely unlikable, 9 = extremely likable). Participants responded by clicking on numbered options with the mouse. There was no time limit for responses; the next photo appeared immediately after each rating.

Personality Adjective Self-Descriptiveness Rating: Participants viewed 40 personality adjectives in random order and rated how well each word described themselves on a 9-point scale (1 = does not describe me at all, 9 = describes me very well). Again, participants used mouse clicks to respond with no time limit between trials.

2.3.3 Emotion Regulation Phase (EEG Recording)

Participants first completed approximately 15 minutes of emotion regulation practice. During practice, the experimenter explained in detail the requirements and key points for each regulation strategy ("watch," "reappraise," and "distract") and had participants practice each strategy until they fully understood them before proceeding to the next phase. Specifically, for "watch," participants simply viewed the peer photos and feedback naturally without intervening in any thoughts or emotional experiences that arose. For "reappraise," participants were instructed to change their thoughts about the negative social feedback to reduce negative emotional experience, for example by thinking "I am not such a person; if the peer in the photo had a chance to know me, they would change their opinion" (Nasso et al., 2020). For "distract," participants were instructed to focus their attention on neutral thoughts unrelated to the current situation (Zhao et al., 2021).

After practice, participants completed the formal emotion regulation task, which consisted of three blocks of 40 trials each, presented in random order. The trial procedure is illustrated in Figure 1B. Each trial began with a fixation point presented for 0.8–1 s, followed by a 3-s emotion regulation instruction ("watch," "reappraise," or "distract"). After another fixation point (0.3–0.5 s), the peer' s photo and their social feedback about the participant (e.g., "She thinks you are lazy," "He thinks you are honest") were presented simultaneously for 6 s. During this 6-s period, participants executed the previously shown regulation strategy to regulate their emotional response to the social feedback. Following this, participants rated their current emotional experience on a 9-point scale (1 = very negative, 5 = neutral, 9 = very positive) by clicking on numbered options with the mouse. After completing the rating, the next trial began. Participants received a break after each block. The emotion regulation task comprised 120 trials total, with 30 trials per condition. EEG activity was recorded throughout the task.

After completing the task, participants filled out the "Emotion Regulation Task Instruction Compliance Questionnaire" (see Appendix 1). This questionnaire contained four items rated on a 5-point scale, with higher scores indicating greater compliance with the instructions. Participants with total scores below 12 were considered to have followed instructions in fewer than 60% of trials, and their data were excluded from analysis (2 participants).

2.3.4 Immediate Post-Test Phase

This phase included three tasks administered in sequence: peer likability rating, memory test, and personality adjective self-descriptiveness rating. The first and third tasks were identical to those in the baseline phase (see Section 2.3.2).

Memory Test: The 40 peer photos were presented in random order. Participants had 5 s to recall each person' s evaluation of them and verbally report it into a recording device. The instructions were: "Next, photos of peers will be presented in random order. Please recall their evaluation of you within 5 s and answer into the recording device. If you remember the specific word, report it; if you only remember whether it was positive or negative but not the specific word, you may answer 'positive' or 'negative' ; if you don' t remember at all, answer 'don' t remember.' Your voice will be recorded. The next photo will appear automatically after 5 s."

2.3.5 Delayed Post-Test Phase

Twenty-four hours after the emotion regulation experiment, participants returned to the laboratory for the delayed post-test, which used the same tasks as the immediate post-test.

2.4 EEG Recording and Processing

EEG data were recorded using a 32-channel Brain Products recording system with an actiCHamp amplifier and corresponding EEG cap (Brain Products, Munich, Germany) at a sampling rate of 250 Hz. During recording, FCz served as the online reference electrode, AFz as the ground electrode, and impedance for all electrodes was maintained below 10 KΩ.

Offline preprocessing was conducted using EEGLAB (Delorme & Makeig, 2004) and ERPLAB toolboxes (Lopez-Calderon & Luck, 2014) in MATLAB R2019a (MathWorks). Data were re-referenced to the average of all electrodes and bandpass filtered between 0.01–40 Hz. The data were then segmented into epochs from 200 ms before to 6 s after social feedback onset. Independent component analysis implemented in EEGLAB was used to correct for ocular artifacts, and trials with amplitudes exceeding $±$100 µV were rejected as noise.

For univariate ERP analysis, we examined the LPP component, which is most commonly investigated in emotion regulation research. Baseline correction was performed using the 200 ms pre-feedback interval, and ERP waveforms were obtained by averaging valid trials. Based on previous literature, LPP amplitude reflecting changes in emotional experience typically reaches maximum values at central-parietal sites (Hajcak & Nieuwenhuis, 2006; Thiruchselvam et al., 2011). Given that our emotion regulation task design closely resembled that of Hajcak and Nieuwenhuis (2006), we selected the average amplitude across CP1 and

CP2 electrodes within the 600–1000 ms time window as our central-parietal LPP measure.

For MVPA, we employed machine learning methods to conduct between-condition decoding analysis based on averaged ERPs. This analysis was performed using modified scripts in MATLAB (adapted from publicly available scripts; Bae & Luck, 2018). A one-versus-one support vector machine (SVM) model was used for within-subject classification of "watch-reappraisal" and "watch-distraction" conditions. First, valid EEG trials for each regulation condition were randomly divided into three groups. EEG data within each group were averaged across trials in the time domain to create sub-ERPs, thereby improving signal-to-noise ratio and enhancing decoding effectiveness. We then used sub-ERP amplitudes from 28 valid electrodes (excluding ocular, reference, and ground electrodes) as features to conduct three-fold cross-validation decoding on each participant' s data from -200 to 6000 ms. During each decoding iteration, two sub-ERPs served as the training dataset for SVM classifier training after normalization, while the remaining sub-ERP was reserved as the test dataset. SVM classifier training was performed at each 40 ms time point (downsampled to 25 Hz) and repeated for 10 iterations. The test dataset was then normalized using the mean and standard deviation of the training dataset and subjected to binary classification (i.e., determining which condition the current data belonged to). Classification accuracy was compared against chance level (50%). This analytical approach is commonly used to investigate neural dynamics differences between conditions (Carlson et al., 2019; Hebart & Baker, 2018).

Additionally, to examine the contribution of individual electrodes to between-condition decoding accuracy, we conducted searchlight decoding analysis (Treder, 2020). This analysis used the 28 valid electrodes as features and performed averaging within 1000 ms time windows from 0 to 6000 ms to detect electrode distributions contributing to decoding accuracy across different time windows. For each electrode, the decoding features included amplitudes from that electrode and its neighboring electrodes. Subsequent analyses followed the same procedure as the ERP-based between-condition decoding described above.

2.5 Statistical Methods

Statistical analyses of behavioral measures and ERP amplitudes were conducted using jamovi 1.0.7.0 (https://www.jamovi.org). Single-factor repeated-measures ANOVA was used with significance level set at $\alpha = 0.05$. Unless otherwise specified, descriptive statistics are reported as "mean ± standard deviation."

For between-condition decoding and searchlight analyses, one-sample t-tests (one-tailed) were used to compare decoding accuracy at each time point from 0–6000 ms against chance level (0.5). Non-parametric cluster-based Monte-Carlo permutation testing with 5000 iterations was used to control for multiple comparisons, with significance level set at $\alpha = 0.05$.

Additionally, Pearson correlations were used to examine relationships among behavioral measures, LPP amplitudes, and depression levels, while Spearman correlations were used to examine relationships between between-condition decoding accuracy and behavioral measures.

In the main text, we report behavioral results from 66 participants. We also analyzed behavioral data from the 45 participants included in the EEG analysis, and the results showed highly consistent patterns with those from the full sample (see Appendix 2).

3.1 Emotion Ratings in the Emotion Regulation Task

One-sample t-tests revealed that participants' emotion ratings in the positive watch condition (6.59 ± 0.76) were significantly higher than 5 (neutral emotion), $t(65) = 17.07$, $p < 0.001$, Cohen' s $d = 2.10$. Emotion ratings in the negative watch condition (4.14 ± 0.81) were significantly lower than 5, $t(65) = -8.70$, $p < 0.001$, Cohen' s $d = -1.07$. Paired t-tests showed that emotion ratings in the positive watch condition were significantly higher than in the negative watch condition, $t(65) = 16.2$, $p < 0.001$, Cohen's $d = 1.99$. These results demonstrate the effectiveness of our experimental manipulation, confirming that positive and negative social feedback elicited corresponding emotional responses (Nasso et al., 2020).

Repeated-measures ANOVA on the three negative conditions (negative watch, negative reappraisal, negative distraction) revealed a significant main effect of emotion regulation, $F(2, 130) = 66.6$, $p < 0.001$, 2 p = 0.506 (Figure 1C). Follow-up simple effects analyses showed that compared to the negative watch condition (4.14 ± 0.81), emotion ratings were significantly more positive in both the negative reappraisal (5.33 ± 0.95, $p < 0.001$) and negative distraction (5.10 ± 0.78, $p < 0.001$) conditions. Additionally, ratings in the negative reappraisal condition were significantly higher than in the negative distraction condition ($p = 0.035$), indicating that reappraisal was more effective than distraction in this paradigm.

3.2.1 Effects of Emotion Regulation on Peer Likability

Change scores were calculated by subtracting baseline ratings from immediate post-test ratings. The results showed no significant effect of emotion regulation, $F(2, 130) = 1.61$, $p = 0.203$, 2 p = 0.024. No significant differences were found among the negative watch (-0.39 ± 0.77), negative reappraisal (-0.35 ± 0.70), and negative distraction (-0.26 ± 0.82) conditions ($ps \geq 0.081$). These results suggest that participants' likability ratings of peers were not significantly affected by emotion regulation.

3.2.2 Effects of Emotion Regulation on Memory

Participants' recall responses were quantified along two dimensions: accuracy for the valence of social feedback (positive or negative; hereafter “valence accuracy”) and accuracy for the specific feedback words (hereafter “word accuracy”).

For valence accuracy, the main effect of emotion regulation was significant, $F(2, 130) = 7.80$, $p < 0.001$, 2 $p = 0.107$ (Figure 2A). Follow-up simple effects analyses revealed that valence accuracy was lower in both the negative reappraisal (0.43 ± 0.27, $p = 0.007$) and negative distraction (0.41 ± 0.25, $p < 0.001$) conditions compared to the negative watch condition (0.50 ± 0.25). No significant difference was found between reappraisal and distraction conditions ($p = 0.283$). Thus, both reappraisal and distraction reduced memory for the valence of negative social feedback.

For word accuracy, the main effect of emotion regulation was also significant, $F(2, 130) = 10.0$, $p < 0.001$, 2 $p = 0.134$ (Figure 2B). Follow-up analyses showed that word accuracy was lower in both the negative reappraisal (0.03 ± 0.07, $p < 0.001$) and negative distraction (0.03 ± 0.07, $p < 0.001$) conditions compared to the negative watch condition (0.07 ± 0.10). Again, no significant difference was found between reappraisal and distraction conditions ($p = 0.555$). Therefore, both strategies reduced memory for the specific words of negative social feedback.

It should be noted that since participants were not explicitly instructed to memorize the social feedback during the emotion regulation task, word recall accuracy showed a floor effect (all conditions $< 10\%$). Nevertheless, both valence accuracy and word accuracy showed consistent patterns, with reappraisal and distraction reducing memory for negative social feedback compared to passive watching.

Additionally, we examined the relationship between positive memory bias for social feedback (difference between positive and negative watch conditions) and depression level. Results showed that depression level was negatively correlated with positive memory bias for both valence accuracy ($r = -0.249$, $p = 0.044$) and word accuracy ($r = -0.272$, $p = 0.027$), consistent with previous findings (Saunders, 2011; Xie et al., 2022).

3.2.3 Effects of Emotion Regulation on Self-Descriptiveness Ratings of Personality Adjectives

Change scores were calculated by subtracting baseline ratings from immediate post-test ratings. The results showed no significant main effect, $F(2, 130) = 0.502$, $p = 0.606$, 2 $p = 0.008$. No significant differences were found among the negative watch (-0.44 ± 0.75), negative reappraisal (-0.51 ± 0.63), and negative distraction (-0.44 ± 0.70) conditions ($ps \geq 0.369$). These results indicate that participants' self-descriptiveness ratings of personality adjectives were not affected by emotion regulation.

3.3 Delayed Post-Test

Two participants did not return to the laboratory on the second day, resulting in a sample size of 64 for this phase. As participants' performance on peer likability and self-descriptiveness rating tasks showed the same pattern as in the immediate post-test, these results are not described in detail here.

For the memory test, valence accuracy showed a significant main effect of emotion regulation, $F(2, 126) = 8.11$, $p < 0.001$, 2 p = 0.114 (Figure 2C). Follow-up analyses revealed lower valence accuracy in both reappraisal (0.33 ± 0.23, $p = 0.003$) and distraction (0.32 ± 0.23, $p < 0.001$) conditions compared to the watch condition (0.40 ± 0.23). No significant difference was found between reappraisal and distraction conditions ($p = 0.467$). Thus, the effect of emotion regulation on valence accuracy was long-lasting, persisting into the second day.

For word accuracy, the main effect of emotion regulation was not significant, $F(2, 126) = 2.30$, $p = 0.104$, 2 p = 0.035 (Figure 2D). However, pairwise comparisons showed that word accuracy was lower in the reappraisal condition (0.02 ± 0.05, $p = 0.040$) compared to the watch condition (0.03 ± 0.07). No significant difference was found between watch and distraction (0.02 ± 0.05) conditions ($p = 0.134$), nor between reappraisal and distraction conditions ($p = 0.572$).

3.4 Effects of Emotion Regulation on ERPs

The main effect of emotion regulation on LPP amplitude was significant, $F(2, 88) = 3.57$, $p = 0.032$, 2 p = 0.075 (Figure 3B). Pairwise comparisons revealed that LPP amplitude in the negative distraction condition (0.71 ± 2.16 µV) was significantly lower than in the negative reappraisal condition (1.33 ± 2.22 µV; $p = 0.011$). Compared to the negative watch condition (1.16 ± 2.09 µV), LPP amplitude in the negative distraction condition was marginally lower ($p = 0.066$). No significant difference was found between negative watch and negative reappraisal conditions ($p = 0.467$).

Furthermore, LPP amplitude in the distraction condition was negatively correlated with participants' depression scores, $r = -0.386$, $p = 0.009$ (Figure 3C).

3.5 Between-Condition Multivariate Decoding Based on ERPs

To further investigate how depression level influences EEG activity patterns during emotion regulation, we divided participants into high and low depression groups based on a cutoff score of 13 on the BDI-II (Beck et al., 1987).

Results showed that in the low depression group, whole-brain EEG activity patterns could distinguish between negative watch and negative reappraisal conditions within the time window of 2120–5360 ms (p corrected < 0.05, Figure 4A), primarily relying on frontal and parietal electrodes (Figure 4F). However, no significant discrimination was found between negative watch and negative distraction conditions at any time window (Figure 4B). In contrast, the high depression group showed the opposite pattern: whole-brain EEG activity could distinguish between negative watch and negative distraction conditions within 2040–3000 ms (p corrected < 0.05, Figure 4E), though searchlight analysis did not identify any individual electrode channels making significant contributions (Figure 4G). No significant discrimination was found between negative watch and negative reappraisal conditions at any time window in the high depression group (Figure 4D).

Additionally, within the 2120–5360 ms time window, decoding accuracy for watch versus reappraisal conditions was positively correlated with the difference in valence accuracy between these conditions in the immediate memory test (negative watch minus negative reappraisal), $r(43) = 0.295$, $p = 0.049$ (Figure 4C). This suggests that neural activity differences during emotion regulation can predict the extent to which cognitive reappraisal reduces memory for negative social feedback.

Negative social feedback in social interactions often causes significant psychological stress and emotional distress, representing a major precipitating factor for many psychiatric disorders such as depression and social anxiety (Rappaport & Barch, 2020; Reinhard et al., 2020). The present study found that both cognitive reappraisal and distraction effectively attenuated emotional responses to negative social feedback and promoted adaptive forgetting of such feedback. We propose that using these emotion regulation strategies can help individuals better cope with negative feedback in daily life, fostering a virtuous cycle between emotion and memory, and ultimately facilitating successful social integration and maintenance of healthy relationships (Figure 5). Additionally, we found that participants' depression levels significantly influenced whole-brain EEG activity patterns associated with different emotion regulation strategies: compared to the baseline watch condition, low-depression individuals showed significantly different brain activity patterns during reappraisal, whereas high-depression individuals showed significantly different patterns during distraction, with better emotion regulation effectiveness (i.e., greater reduction in negative emotional responses) when using distraction. Overall, this study broadens our understanding of the emotion-memory relationship from novel perspectives of social emotion regulation and motivated forgetting, enriches the cognitive neuroscience of how emotion regulation influences social emotion and memory, and provides valuable insights for alleviating social pain in depressed individuals.

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Appendix 1: Emotion Regulation Task Instruction Compliance Questionnaire

Please answer the following questions honestly based on your performance in the task just completed:

1. Did you completely follow the instructions during the task (i.e., watch when instructed to watch, reappraise when instructed to reappraise, distract when instructed to distract)? Please rate on a scale of 1 to 5: 1 = did not follow at all, 5 = completely followed.
2. For the "watch" task, in what percentage of trials did you naturally watch and experience without intervening in your feelings? Please rate on a scale of 1 to 5: 0-20% 21-40% 41-60% 61-80% 81-100%
3. For the "reappraisal" task, in what percentage of trials did you change your thoughts about the negative evaluation? Please rate on a scale of 1 to 5: 0-20% 21-40% 41-60% 61-80% 81-100%
4. For the "distraction" task, in what percentage of trials did you shift your attention to unrelated neutral thoughts/things? Please rate on a scale of 1 to 5: 0-20% 21-40% 41-60% 61-80% 81-100%

Supplementary Results for EEG Subsample (N = 45)

3.1 Emotion Ratings in the Emotion Regulation Task

Paired t-tests showed that participants' emotion ratings in the positive watch condition (6.55 ± 0.76) were significantly higher than in the negative watch condition (4.14 ± 0.80), $t(44) = 13.0$, $p < 0.001$, Cohen' s $d = 1.93$, demonstrating the effectiveness of our experimental manipulation.

Repeated-measures ANOVA on the three negative conditions revealed a significant main effect of emotion regulation, $F(2, 88) = 41.6$, $p < 0.001$, 2 p = 0.486. Follow-up simple effects analyses showed that compared to the negative watch condition (4.14 ± 0.80), emotion ratings were significantly more positive in both the reappraisal (5.26 ± 0.87, $p < 0.001$) and distraction (5.06 ± 0.74, $p < 0.001$) conditions. Ratings in the reappraisal condition were higher than in the distraction condition, but this difference was not significant ($p = 0.130$).

3.2.1 Effects of Emotion Regulation on Peer Likability

Change scores were calculated by subtracting baseline ratings from immediate post-test ratings. The results showed no significant effect of emotion regulation, $F(2, 88) = 2.17$, $p = 0.120$, 2 p = 0.047. No significant differences were found among the negative watch (-0.34 ± 0.68), negative reappraisal (-0.20 ± 0.57), and negative distraction (-0.18 ± 0.72) conditions (ps ≥ 0.059).

3.2.2 Effects of Emotion Regulation on Memory

For valence accuracy, the main effect of emotion regulation was significant, F(2, 88) = 6.63, p = 0.002, 2 p = 0.131. Follow-up simple effects analyses revealed that valence accuracy was lower in both the reappraisal (0.41 ± 0.25, p = 0.042) and distraction (0.36 ± 0.23, p < 0.001) conditions compared to the watch condition (0.48 ± 0.26). No significant difference was found between reappraisal and distraction conditions (p = 0.121). Thus, both strategies reduced memory for the valence of negative social feedback.

For word accuracy, the main effect of emotion regulation was also significant, F(2, 88) = 4.55, p = 0.013, 2 p = 0.094. Follow-up analyses showed that word accuracy was lower in both the reappraisal (0.03 ± 0.07, p = 0.014) and distraction (0.03 ± 0.07, p = 0.008) conditions compared to the watch condition (0.06 ± 0.10). No significant difference was found between reappraisal and distraction conditions (p = 0.858).

3.2.3 Effects of Emotion Regulation on Self-Descriptiveness Ratings of Personality Adjectives

Change scores were calculated by subtracting baseline ratings from immediate post-test ratings. The results showed no significant main effect, F(2, 88) = 0.105, p = 0.901, 2 p = 0.002. No significant differences were found among the negative watch (-0.45 ± 0.60), negative reappraisal (-0.48 ± 0.59), and negative distraction (-0.49 ± 0.60) conditions (ps ≥ 0.656).

3.3 Delayed Post-Test

Participants' performance on peer likability and self-descriptiveness rating tasks showed the same pattern as in the immediate post-test and are not described in detail here.

For the memory test, valence accuracy showed a significant main effect of emotion regulation, F(2, 86) = 6.05, p = 0.003, 2 p = 0.123. Follow-up analyses revealed lower valence accuracy in both reappraisal (0.32 ± 0.22, p = 0.041) and distraction (0.28 ± 0.20, p < 0.001) conditions compared to the watch condition (0.37 ± 0.22). No significant difference was found between reappraisal and distraction conditions (p = 0.170).

For word accuracy, the main effect of emotion regulation was not significant, F(2, 86) = 1.38, p = 0.257, 2 p = 0.031. No significant differences were found among the negative watch (0.03 ± 0.06), negative reappraisal (0.01 ± 0.04), and negative distraction (0.02 ± 0.06) conditions (ps ≥ 0.101).

Note: Figure translations are in progress. See original paper for figures.