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Emotion regulation modulates subsequent control of unwanted memories

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Abstract

Emotion regulation and memory control are indispensable for well-being, yet their interplay remains poorly understood. In this preregistered electroencephalogram (EEG) study, we investigated how emotion regulation influences the subsequent control of negative memories. Participants learned object-aversive scene pairings and were then instructed to either naturally watch or actively reappraise the aversive scenes. They subsequently completed an EEG-based Think/No-Think (TNT) task, where they either retrieved or suppressed the retrieval of aversive scenes in response to Think or No-Think object cues while reporting any intrusions they experienced. Different from our initial hypothesis, preregistered analyses showed that during retrieval suppression, reappraised memories were associated with larger centro-parietal P300 than watched scenes. Consistently, in the post-TNT recall test, participants recalled more details and reported lower negative emotions related to these reappraised scenes than the watched scenes. These results suggest that cognitive reappraisal may preserve the episodic content of negative memories while lessening their emotional impact during recall. This finding holds significant clinical potential, as it could enable individuals to retain valuable information from adverse experiences without being overwhelmed by distress. Additionally, it may help address reduced memory specificity in affective disorders, offering a promising avenue for therapeutic intervention.

Keywords **emotion regulation, memory control, voluntary forgetting, Think/No-Think, event-related potential**

Introduction

The ability to control unwanted memories is crucial for mental health, particularly after adversity (Engen and Anderson 2018, Mary *et al.* 2020, Fawcett *et al.* 2024). Memory control (MC) strategies can limit the encoding and retrieval of unwanted memories, promoting forgetting (Hu *et al.* 2017, Anderson and Hulbert 2021), while emotion regulation (ER) strategies like reappraisal reduce negative affect (Garnefski *et al.* 2001, Webb *et al.* 2012, Gross *et al.* 2019).

Despite known links between emotion and memory (LeDoux 1994, Dolan 2002, Phelps 2006, Kensinger and Ford 2020), the interaction between ER and MC remains poorly understood. Clarifying this interplay is theoretically critical and has translational importance, as impairments in both processes are transdiagnostic risk factors for psychiatric disorders such as depression, anxiety, and post-traumatic stress disorder.

Theoretical framework and directionality

Emerging evidence indicates a close relationship between ER and MC. Neurobiologically, a meta-analysis suggests that both ER and MC rely on prefrontal top-down regulation of limbic regions such as the

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amygdala and hippocampus (Liu *et al.* 2020). Behaviorally, individuals who frequently use reappraisal in daily life show better laboratory-based memory control performance (Yang *et al.* 2021).

Recent theoretical models have begun to map the relationship between ER and MC. Engen and Anderson (2018) posited that successful control of unwanted memories can effectively regulate one's emotional reactions. Similarly, the Mnemonic Emotion Regulation model posits that adaptive memory control processes (rehearsal, inhibition, and construction) support emotion regulation (Nørby 2019). Building upon these ideas, Luo *et al.* (2024) proposed a model elucidating the bi-directional influences between MC and ER: MC impacts ER by enhancing desirable memories and by updating or forgetting undesirable memories. Conversely, ER modulates MC by bolstering positive emotions and dampening negative emotions (Luo *et al.* 2024). This framework delineates how MC and ER reciprocally influence each other, thereby providing testable hypotheses and directions for subsequent empirical investigations.

Within this bidirectional framework, the specific influence of ER on subsequent MC warrants particular attention, as it may help resolve persistent inconsistencies in the memory control literature. Repeatedly suppressing the retrieval of unwanted memories can lead to episodic forgetting of suppressed memories, a phenomenon known as suppression-induced forgetting (SIF; Anderson and Green 2001, Fawcett *et al.* 2024). Research using the Think/No-Think (TNT) paradigm (Anderson and Green 2001) has yielded mixed results regarding the suppression of emotional memories. Specifically, Depue *et al.* (2006) reported that suppression is more effective for negative memories, leading to higher SIF for negative than neutral content. Conversely, other research indicates that negative memories are harder to suppress. Chen *et al.* (2012) found lower SIF for negative memories, a result supported by neural evidence of heightened recollection-related activity during suppression attempts. This aligns with the neuroimaging findings of Butler and James (2010). Furthermore, several studies have observed comparable SIF for negative and neutral memories (Murray *et al.*, 2011, van Schie *et al.*, 2013). A potential explanation for these inconsistencies is the heterogeneity in the emotional intensity of stimuli used across studies, where highly arousing materials may impair suppression efficacy (Marx *et al.* 2008). This points to a critical theoretical gap: if high emotional intensity impedes memory control, then proactively dampening that intensity through ER should, in principle, unburden the control system and facilitate subsequent voluntary forgetting.

Selection of reappraisal strategy

We propose that cognitive reappraisal, an antecedent-focused ER strategy (Gross 1998a), is ideally suited for this purpose. By reinterpreting the meaning of an emotional stimulus before a full-blown emotional response unfolds, reappraisal effectively down-regulates subjective negative affect and reduces amygdala reactivity (Webb *et al.* 2012, Nelson *et al.* 2015, He *et al.* 2023). Although expressive suppression (inhibiting emotion-expressive behavior) may superficially resemble memory suppression (inhibiting retrieval), it is a response-focused strategy that operates late in the emotion-generative process (Gross 1998b, Zhang *et al.* 2025). It is cognitively costly and often fails to reduce the subjective experience of negative affect or physiological arousal (Richards and Gross 2000, Gross 2002, Sikka *et al.* 2022). As such, engaging in emotional suppression may impose an additional cognitive burden that interferes with, rather than facilitates, the demanding process of memory control. By contrast, reappraisal mitigates the root cause of suppression difficulty (i.e. emotional intensity) by altering the interpretation of an unwanted memory to make it less negative, all without the high cognitive cost associated with late-stage strategies.

In addition, from a therapeutic perspective, cognitive reappraisal is a cornerstone of interventions such as cognitive-behavioral therapy (Beck 2005). However, when applied during encoding, its effect on memory strength has yielded inconsistent findings, sometimes enhancing, weakening, or producing no change in subsequent memory (Richards and Gross 2000, Richards *et al.* 2003, Egloff *et al.* 2006, Sheppes and Meiran 2008, Hayes *et al.* 2010, Davis and Levine 2013, Xie *et al.* 2023). Crucially, whether and how reappraisal causally influences subsequent memory control during retrieval, and its underlying neurocognitive mechanisms, remains unexplored. Elucidating this role is essential for building a comprehensive framework that bridges emotion regulation and memory control, ultimately informing therapeutic approaches aimed to enhancing adaptive memory functioning.

Neural mechanisms

Neuroimaging studies of the TNT paradigm identify a core suppression network wherein prefrontal control regions downregulate hippocampal activity to induce forgetting (Anderson *et al.* 2004, Benoit and Anderson 2012, Gagnepain *et al.* 2017, Anderson and Floresco 2022), a process predicted by DLPFC-hippocampal connectivity (Levy and Anderson 2012, Paz-Alonso *et al.* 2013). Electrophysiological markers further delineate this temporal dynamics: the fronto-central N450 reflects engaged inhibitory control (Bergström *et al.* 2009, Mecklinger *et al.* 2009, Chen *et al.* 2012, Zhang *et al.* 2016, Lin *et al.* 2024), while a reduced parietal P300 indicates suppressed recollection (Bergström *et al.* 2009, Mecklinger *et al.* 2009, Depue *et al.* 2013, Hu *et al.* 2015, Zhang *et al.* 2016, Chen *et al.* 2022, Lin *et al.* 2024).

In addition, the late-positive potential (LPP) is a robust electrophysiological index of emotional processing, with its amplitude positively correlating with subjective arousal intensity (Dean *et al.* 2007, Liu *et al.* 2012). Furthermore, the successful implementation of emotion regulation strategies like reappraisal effectively reduces both negative experience and LPP amplitude (Hajcak and Nieuwenhuis 2006, Hajcak *et al.* 2010, Thiruchselvam *et al.* 2011, Schönfelder *et al.* 2014, Zhao *et al.* 2021, Li *et al.* 2022).

The present research

Here, we investigated how cognitive reappraisal causally impacts subsequent retrieval suppression in the TNT paradigm (Anderson and Green 2001, Fig. 1a). Since cognitive reappraisal usually reduces emotional intensity (Gross 2002, Gross and John 2003, Hajcak and Nieuwenhuis 2006), we preregistered the hypothesis that reappraising negative memories would facilitate their subsequent retrieval suppression. Behaviorally, we predicted that compared to a "watch" condition, reappraisal would reduce intrusion rates during the TNT task and enhance forgetting in a final recall test.

A secondary goal of this study was to examine how emotion regulation (ER) and memory control (MC) influence the subjective emotional experience of negative memories. We assessed valence ratings at three time points: baseline, post-ER (immediately after reappraisal or passive viewing), and post-TNT recall. This allowed us to compute two complementary measures: the overall change from baseline to

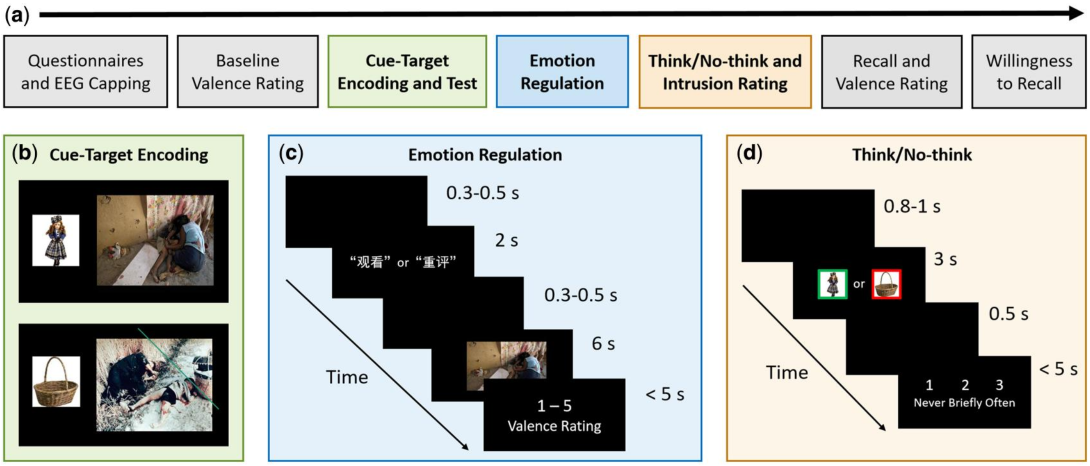

Figure 1 Experimental procedures. (a) Participants completed seven phases in the experiment. (b) Examples of the cue-target pairings. (c) An exemplar trial illustrating the emotion regulation (ER) task. (d) An exemplar trial illustrating the Think/No-Think (TNT) task.

post-TNT recall (combined effect of ER and MC), and the change from post-ER to post-TNT recall (effect specifically attributable to the MC phase). We predicted that reappraisal would reduce negativity from baseline to post-ER, and that the TNT task would produce further emotional down-regulation, particularly for memories that had not been reappraised (Gagnepain *et al.* 2017).

Beyond the behavioral measures, we used electroencephalography (EEG) to examine the underlying neurocognitive processes. We preregistered our hypothesis that reappraisal would enhance the neural efficacy of suppression. Specifically, we expected that suppressing reappraised (vs. watched) memories would require less inhibitory control and recollection, manifesting as smaller N450 and P300 amplitudes during No-Think trials. Furthermore, we predicted that suppressing reappraised memories would result in diminished emotional responses, as reflected by reduced LPP amplitudes.

As an exploratory component of this study, we also examined the relationships between all behavioral indices (including emotion regulation success, memory control performance, and valence changes at different time points) and all neural markers (including N450, P300, and LPP amplitudes). No preregistered directional hypotheses were made for these correlations. Instead, these analyses aimed to examine correlations both among behavioral indices and between behavioral performance and neural dynamics during memory control, thereby providing preliminary insights and generating testable hypotheses for future research.

Methods

Transparency and openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and the study follows JARS (Appelbaum *et al.* 2018). Preregistration is available at https://osf.io/78m2a/.

Participants

Based on a priori power analysis, we pre-registered to recruit 60 valid participants. To account for potential exclusions (e.g. low task compliance or excessive EEG artifacts), we recruited 69 right-handed, native Chinese speakers from the University of Hong Kong. All participants have the normal or corrected-to-normal vision and no history of neurological or psychiatric disorders. In accordance with the preregistered exclusion criterion, twenty-four participants were excluded due to low compliance on the TNT task, operationalized as a score of 7 or higher on the three-item post-TNT compliance questionnaire (Liu *et al.* 2021, Lin *et al.* 2024, Nardo and Anderson 2024). Among these participants, eight scored 7, eleven scored 8, two scored 9, one scored 10, and two scored 11. Additionally, one participant was excluded for pressing the wrong key during the TNT task, resulting in invalid behavioral data. These exclusions yielded a final sample of 44 participants for the behavioral analyses (12 males; mean age = 23.2 ± 3.3 years). For the EEG analyses, eight additional participants were excluded due to excessive artifacts (fewer than 60% clean trials), resulting in a final sample of 36 participants (10 males; mean age = 23.6 ± 3.3 years). Our final sample size ($N = 44$ for behavioral analyses; 36 for EEG analyses) is comparable to, and higher than that of previous emotional TNT studies (e.g., $n = 18$ in Catarino *et al.* 2015; $n = 24$ in Gagnepain *et al.* 2017; $n = 24$ in Küpper *et al.* 2014; $n = 29$ in Depue *et al.* 2013; $n = 30$ in Nishiyama and Saito 2022; $n = 30$ per group in Harrington *et al.* 2021; $n = 32$ Hellerstedt *et al.* 2016; $n = 40$ in Lin *et al.* 2024). The study was approved by the Human Research Ethics Committee of The University of Hong Kong. All participants provided written informed consent before the study and received monetary incentives (60 HKD/hour) for their participation.

Materials

We used 48 object-scene picture pairs from Küpper *et al.* (2014). Scenes were 32 negative and 16 neutral pictures from the International Affective Picture System (IAPS; Lang *et al.* 2008) and online sources, each paired with a neutral object sharing its features (examples are shown in Fig. 1b). Pairs were distributed across the six conditions from our 3 (*ER*: Negative-Watch, Negative-Reappraisal, Neutral-Watch) × 2 (*TNT*: Think, No-Think) design. Participants rated scene negativity on a 5-point scale (1 = neutral or not negative at all, 5 = extremely negative); baseline valence is in Table S1 (see online supplementary material for a color version of this table). Eight additional negative scenes were used for practice.

The 32 negative social feedback items were divided into four sets (A, B, C, D), and the 16 neutral items were divided into two sets (E, F). A between-participants Latin-square-like design was employed to assign these sets to experimental conditions. Specifically, the four negative sets were counterbalanced across the four negative conditions (Watch-Think, Watch-NoThink, Reappraisal-Think, Reappraisal-NoThink), and the two neutral sets were counterbalanced across the two neutral conditions (Think, NoThink). Thus, each stimulus set appeared equally often in each condition across participants, ensuring that any idiosyncratic features of specific items were evenly distributed and did not systematically bias the results.

Experimental design and procedure

The study was a 3 (*ER*: Negative-Watch, Negative-Reappraisal, and Neutral-Watch) × 2 (*TNT*: Think vs. No-Think) within-subject design. Exemplar materials in each condition are shown in the Supplementary Material (Figure S1, see online supplementary material for a color version of this figure). We included the Neutral-Watch condition to serve as a control to assess the valence effect (e.g. Negative-Watch vs. Neutral-Watch).

After arriving at the laboratory, participants completed questionnaires and then the following tasks in order (Fig. 1a).

Baseline valence rating

Participants rated the negativity of 48 scenes (5-point scale) within 5 s each.

Object-scene pairings encoding

Participants viewed 48 object-scene pairs for 6 s each to form strong associations for later recall.

Recognition with feedback

Participants were tested on their memory for the pairs. For each object cue, participants had 4 s to indicate if they recalled the scene. If "yes," they had 4 s to choose the correct scene from two foils. Corrective feedback (object-scene pairing) was then displayed for 2.5 s. This cycle repeated until performance reached ≥80% accuracy.

Emotion regulation task

Participants first completed a practice session to familiarize themselves with the trial conditions. Participants were given detailed instructions on WATCH ("观看" in Chinese) and REAPPRAISAL ("重评" in Chinese), and practiced these instructions with eight additional negative pictures. In the WATCH condition, participants were instructed to passively view the presented scene pictures without changing their thoughts or feelings. In contrast, in the REAPPRAISAL condition, participants were instructed to reinterpret the depicted scenes in a way that could make them feel less negative. Taking the upper image in Fig. 1b as an example, a mother and her daughter lie embracing in a broken corner of the wall. This can be interpreted as: "An earthquake occurred, but fortunately, both were quickly rescued with no serious injuries."

Following practice, the main task began. Each trial began with a 2 s instruction cue, followed by a scene for 6 s during which participants performed the WATCH or REAPPRAISAL strategy. Participants then rated their negative feelings within 5 s on a 5-point scale. This task included 16 reappraise-negative, 16 watch-negative, and 16 watch-neutral trials. Post-task, participants rated their compliance and the perceived difficulty of reappraisal on 5-point scales.

TNT task

TNT consisted of eight blocks, with each block containing 48 unique trials. In each block, each of the 48 object pictures was randomly presented for 3 s within a colored frame (green for Think, red for No-Think). On Think trials, participants were required to think of the associated scenes in detail and to keep the scenes in their minds while the objects were presented on the screen. On No-Think trials, participants focused solely on the objects, suppressing any thoughts of the associated scene without using distraction strategies (Bergström *et al.* 2009, Küpper *et al.* 2014, Hu *et al.* 2015, Lin *et al.* 2024). Following each object offset, participants had 5 s to indicate how often the associated scene intruded on their awareness (1 = never, 2 = briefly, 3 = often, see Levy and Anderson 2012; Fig. 1d).

Post-task, participants answered three compliance questions regarding their adherence to the No-Think instructions, using a 5-point scale (0 = never to 4 = always; Liu *et al.* 2021, Nardo and Anderson 2024).

Cued recall and valence rating

Each of the 48 objects was presented randomly. Participants verbally described the associated scene in detail within 15 s, then rated its current negativity on a 5-point scale within 5 s.

Willingness to recall rating

The 48 objects were presented randomly. For each, participants rated their willingness to recall the associated scene on a 5-point scale (1 = extremely unwilling, 5 = extremely willing) within 5 s.

EEG recordings and analysis

Continuous EEGs were recorded during resting-state, ER, and TNT tasks, with the online reference against the CPz using a 64-channel ANT Neuro eego amplifier with a 500 Hz sampling rate (ANT, The Netherlands). Electrode impedances were kept below 20kΩ.

Raw EEG data were preprocessed using the EEGlab Toolbox (Delorme and Makeig 2004) and ERPlab Toolbox (Lopez-Calderon and Luck 2014) in MATLAB R2019a (MathWorks). Data were downsampled to 250 Hz and were filtered using a 0.01–40 Hz band-pass filter, followed by a notch filter of 50 Hz. Bad channels were interpolated before re-referencing to common averages. All EEG analyses were based on data from 61 channels, excluding EOG, M1, M2, AFz (ground), and CPz (online reference).

For the TNT task, continuous EEG data of were segmented into −500 to 3000 ms epochs relative to the object onset, with baseline correction using the mean amplitude of −200 to 0 ms pre-stimulus time window. Ocular and muscle artifacts were corrected via independent component analyses (ICAs; Winkler *et al.* 2011, Pion-Tonachini *et al.* 2019). Epochs contaminated with significant artifacts (exceeding ± 100 μV) were excluded from further analyses.

Based on our preregistration, we analyzed three ERP components during the TNT task: the frontocentral N450, the parietal P300, and the sustained LPP. The N450 amplitude was calculated as the mean amplitude between 300–500 ms from the frontocentral electrodes (FCz, FC1/2, Cz, C1/2). P300 amplitude was calculated as the mean amplitude between 500–800 ms at the left-parietal (P3/5, CP3/5), centro-parietal (Pz, P1/2, CP1/2) and right-parietal electrode sites (P4/6, CP4/6). LPP amplitude was calculated as the mean amplitude between 1000–2000 ms at frontocentral (FCz, FC1/2, Cz, C1/2), centro-parietal (Pz, P1/2, CP1/2), and occipital (POz, PO3/4, Oz, O1/2) electrodes.

Data analyses and statistics

Statistical analysis was performed using jamovi 1.0.7.0 (https://www.jamovi.org) and JASP 0.18.3.0 (https://jasp-stats.org/). Descriptive data are presented as mean ± standard deviation (SD) unless otherwise mentioned.

ER effects were analyzed using repeated-measures ANOVAs, with *Material Type* (Negative-Watch, Negative-Reappraisal, Neutral-Watch) and *Rating phase* (Baseline, Post-ER, Post-TNT recall) as two within-subject factors.

Other behavioral and ERP Indicators were analyzed using repeated-measures ANOVAs, with *ER* (Negative-Watch, Negative-Reappraisal, Neutral-Watch) and *TNT* (Think vs. No-Think) as two within-subject factors. All post-hoc pairwise comparisons and simple effects analyses used Bonferroni-corrected *P*-values to control for multiple comparisons. In addition to omnibus ANOVAs, we also conducted preregistered paired samples t-tests (Negative-Watch-NoThink vs. Negative-Reappraisal-NoThink) on these measures to directly test the effect of reappraisal on memory suppression. Planned contrasts are generally considered acceptable even in the absence of a significant omnibus interaction because they are a priori, hypothesis-driven, and not derived from the data (Allen 2017, Schad *et al.* 2020).

Two-tailed Pearson's *r* correlation analyses were performed between behavioral measures, ERP components, and individual difference scores calculated from questionnaires (see Supplementary Material).

Results

For the sake of clarity, all descriptive data (mean ± SD) for the six within-subject conditions are reported in the Supplementary Material (Table S1, see online supplementary material for a color version of this table).

Behavioral results

Immediate emotion regulation effect: reappraisal reduced negativity

A 3 (*Material Type:* Negative-Watch, Negative-Reappraisal, Neutral-Watch) by 2 (*Rating Phase:* Baseline, Post-ER) repeated-measures ANOVA revealed a significant main effect of *Material Type* ($F(2,86) = 435$, $P < .001$, $\eta^2_p = .910$): participants reported higher ratings (i.e. more negative valence) for Negative-Watch materials than for Negative-Reappraisal and Neutral-Watch materials (both $P < .001$). The main effect of *Rating Phase* was significant ($F(1,43) = 127$, $P < .001$, $\eta^2_p = .747$): emotional valence became less negative in the post-ER rating. Moreover, the *Material Type by Rating Phase* interaction was significant ($F(2,86) = 121$, $P < .001$, $\eta^2_p = .737$). Further simple effects analyses showed that, compared to baseline, participants exhibited reduced negativity ratings for both the Negative-Watch condition ($t(43) = 5.31$, $P < .001$, Bonferroni-corrected, Cohen's $d = 0.80$, 95% confidence interval (CI) [0.46, 1.14]) and the Negative-Reappraisal condition ($t(43) = 14.13$, $P < .001$, Bonferroni-corrected, Cohen's $d = 2.13$, 95% CI [1.59, 2.66]). However, this effect was not significant for the Neutral-Watch condition ($t(43) = 1.87$, $P = 1.000$, Bonferroni-corrected, Cohen's $d = 0.28$, 95% CI [−0.02, 0.58]).

We then calculated the ER effect scores (baseline minus post-ER rating), where higher values indicate greater negativity reduction. These scores were compared between Negative-Reappraisal and Negative-Watch conditions to test the Reappraisal effect, and between Negative-Watch and Neutral-Watch to test the valence effect. Notably, the ER effect of the Negative-Reappraisal condition (mean = 1.19, SE = 0.07) was significantly larger than that of the Negative-Watch condition (mean = 0.38, SE = 0.07; $t(43) = 9.96$, $P < .001$, Cohen's $d = 1.50$, 95% CI [0.65, 0.98]; Fig. 2a). Additionally, the ER effect of the Negative-Watch condition was larger than that of the Neutral-Watch condition (mean = 0.04, SE = 0.07; $t(43) = 5.20$, $P < .001$, Cohen's $d = 0.79$, 95% CI [0.21, 0.47]; Fig. 2a) even no active ER strategies were employed for the Negative-Watch pictures, which may be attributed to habituation.

Retrieval suppression reduced involuntary intrusions across emotion regulation conditions

For the TNT performance, we first calculated the proportion of intrusions (including "briefly" and "often" responses) for each ER × TNT condition. The preregistered omnibus 3 (*ER:* Negative-Watch, Negative-Reappraisal and Neutral-Watch) by 2 (*TNT:* Think and No-Think) repeated-measures ANOVA showed a significant main effect of *TNT* ($F(1,43) = 263.31$, $P < .001$, $\eta^2_p = .860$; Fig. 2b): participants reported significantly fewer intrusions during No-Think than Think trials. The main effect of *ER* was not significant ($F(2,86) = 0.472$, $P = .625$, $\eta^2_p = .011$). Critically, the *ER by TNT* interaction effect was significant ($F(2,86) = 5.08$, $P = .008$, $\eta^2_p = .106$).

To decompose this interaction, simple effects tests were performed. Within the Negative-Watch condition, intrusions were significantly lower in the No-Think condition relative to the Think condition, mean difference = –0.595, $SE = 0.039$, $t = –15.03$, $P < .001$, Bonferroni-corrected. A similar pattern emerged in the Negative-Reappraisal condition, with significantly fewer intrusions in the No-Think than the Think condition, mean difference = –0.593, $SE = 0.039$, $t = –15.18$, $P < .001$, Bonferroni-corrected. In the Neutral-Watch condition, the No-Think condition also yielded reliably lower intrusions compared to the Think condition, mean difference = –0.640, $SE = 0.037$, $t = –17.06$, $P < .001$, Bonferroni-corrected. Follow-up pairwise comparisons further showed that under the Think condition, there were no significant differences among Negative-Watch, Negative-Reappraisal, and Neutral-Watch (all $P = 1.000$, Bonferroni-corrected), and under the No-Think condition, none of the pairwise comparisons between the three ER conditions reached significance (all $P > .05$, Bonferroni-corrected). Together, these results demonstrate that the No-Think instruction consistently reduced memory intrusions across all ER conditions, and while the interactive effect was statistically significant, the inhibitory effect of No-Think remained robust and highly similar across Negative-Watch, Negative-Reappraisal, and Neutral-Watch conditions.

The planned paired samples *t*-test showed no significant differences between Negative-Watch-NoThink vs. Negative-Reappraisal-NoThink conditions, with Bayesian Factor favoring the null hypothesis ($t(43) = –0.24$; $P = .811$, Cohen's $d = –0.04$, 95% CI [–0.33, 0.26], $BF_{01} = 5.96$). As for the Think trials, no *ER* effect was found, i.e. the intrusion proportions were comparable between Negative-Watch-Think, Negative-Reappraisal-Think, and Neutral-Watch-Think conditions (*P*s $\geq .814$, Bonferroni-corrected).

Per preregistered analyses, we next calculated the intrusion slope scores to measure changes in intrusion frequency for No-Think trials from Block 1 to Block 8 of the TNT task. This index indicates participants' efficiencies in down-regulating unwanted involuntary intrusions, with higher scores indicating participants gaining quicker and better control of unwanted intrusions over time (Harrington *et al.*

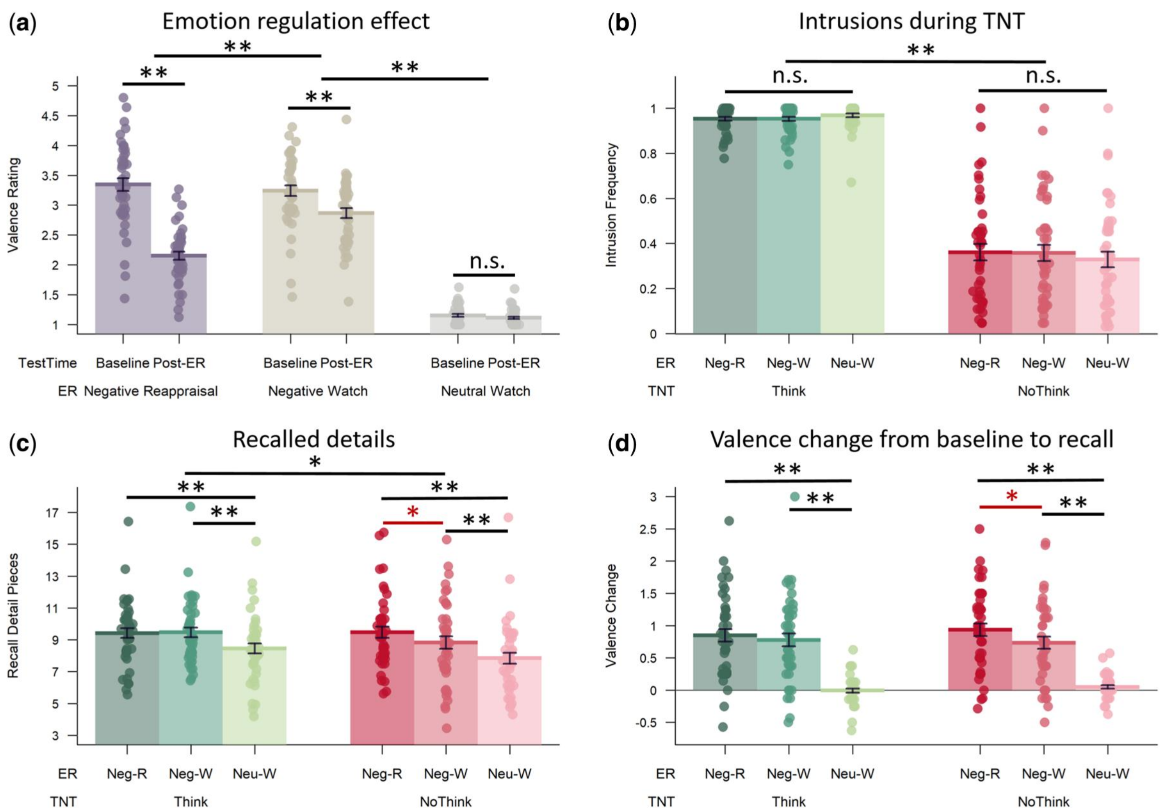

Figure 2 Behavioral results. (a) Valence rating during the baseline and emotion regulation phases. (b) Intrusion proportion during the Think/No-Think phase. (c) Recalled detail pieces in the memory test. (d) Negativity change from baseline to post-TNT recall. Error bars represent the standard error of the mean.

Note. $^{*}P < .05$, $^{**}P < .001$; n.s. indicates non-significance. Black asterisks denote significant effects from ANOVAs, and red asterisks denote significant preregistered pairwise comparisons (*t*-tests). The abbreviation "Neg-W" stands for "Negative-Watch," "Neg-R" stands for "Negative-Reappraisal," and "Neu-W" stands for "Neutral-Watch."

2021). Here we excluded the data of two participants because they had zero intrusion proportions for one of the conditions in the first block, leaving their intrusion slope scores undefined. A repeated-measures (Negative-Watch-NoThink, Negative-Reappraisal-NoThink and Neutral-Watch-NoThink) ANOVA yielded a non-significant effect ($F(2,82) = 0.58$, $P = .563$, $\eta^2_p = .014$). Planned paired samples t-test showed no significant difference between Negative-Reappraisal-NoThink and Negative-Watch-NoThink conditions ($t(41) = 1.53$; $P = .134$, Cohen's $d = 0.24$, 95% CI [–0.07, 0.54], $BF_{01} = 2.05$).

Cued recall performance: effects of reappraisal and retrieval suppression on identification and detail memory

Verbal descriptions from the cued-recall task were scored by two independent raters on two measures: (i) Identification (a binary correct/incorrect score based on scene-identifying details) and (ii) Detail (the count of accurately recalled information segments; Küpper *et al.* 2014). Inter-rater reliability was high for both measures (identification: $r = 1.0$; detail: $r = 0.9$).

On the *identification* measure, the preregistered ANOVA showed a significant TNT effect ($F(1,43) = 8.06$, $P = .007$, $\eta^2_p = .158$): participants recalled fewer No-Think scenes than Think scenes. Also, the main effect of *ER* was significant ($F(2,86) = 3.15$, $P = .048$, $\eta^2_p = .068$). Specifically, participants recalled less Negative-Watch scenes than neutral scenes ($P = .049$, Bonferroni-corrected), while no difference was found between neutral and Negative-Reappraisal scenes ($P = .277$, Bonferroni-corrected), nor between Negative-Watch and Negative-Reappraisal scenes ($P = 1.000$, Bonferroni-corrected). The *ER by TNT* interaction effect was not significant ($F(2,86) = 1.23$, $P = .299$, $\eta^2_p = .028$). A planned paired samples *t*-test showed no significant difference between Negative-Watch-NoThink and Negative-Reappraisal-NoThink conditions ($t(43) = –1.45$; $P = .154$, Cohen's $d = –0.22$, 95% CI [–0.52, 0.08], $BF_{01} = 2.77$).

On the *detail* measure, the preregistered ANOVA showed a significant TNT effect ($F(1,43) = 6.08$, $P = .018$, $\eta^2_p = .124$): participants recalled fewer scene details for No-Think than Think conditions. Also, the *ER* effect was significant ($F(2,86) = 27.08$, $P < .001$, $\eta^2_p = .386$): participants recalled fewer details for neutral scenes than for Negative-Watch or Negative-Reappraisal scenes (both $P < .001$, Bonferroni-corrected), but no significant difference was found between Negative-Watch and Negative-Reappraisal scenes ($P = .500$, Bonferroni-corrected). The *ER by TNT* interaction effect was not significant ($F(2,86) = 1.92$, $P = .153$, $\eta^2_p = .043$). However, our planned paired samples t-test showed that reappraisal led to better memories of details of scenes in the Negative-Reappraisal-NoThink than the Negative-Watch-NoThink condition ($t(43) = 2.08$; $P = .043$, Cohen's $d = 0.31$, 95% CI [0.01, 0.62]; Fig. 2c). Other pairwise comparisons are reported in the Supplementary Material (Table S2, see online supplementary material for a color version of this table).

Combined effect of emotion regulation and memory control on negativity reduction (baseline to final recall)

We assessed valence ratings at three time points: (i) baseline (before any manipulation), (ii) post-ER (immediately after the emotion regulation phase, i.e. reappraisal or passive viewing), and (iii) post-TNT recall (after the TNT task and the cued recall test). To capture the overall emotional change across the entire experiment, we first calculated the *negativity change* from baseline to post-TNT recall (baseline minus post-TNT recall), with higher scores indicating a greater reduction in negativity. This measure thus reflects the combined effect of ER and the TNT task. The preregistered ANOVA only showed a main effect of *ER* (F(2,86) = 75.9, $P < .001$, $\eta^2_p = .638$). Post-hoc comparisons showed smaller negativity change for neutral scenes than for Negative-Watch or Negative-Reappraisal scenes (both $P < .001$, Bonferroni-corrected). However, no significant difference was found between Negative-Reappraisal and Negative-Watch conditions ($P = .051$, Bonferroni-corrected). The *ER by TNT* interaction effect was not significant (F (2,86) = 0.73, $P = .486$, $\eta^2_p = .017$). However, the planned paired samples t-test showed that in the No-Think condition, reappraisal further reduced negativity than watch for aversive scene memories (Negative-Reappraisal-NoThink vs. Negative-Watch-NoThink, t(43) = 2.48; $P = .017$, Cohen's $d = 0.37$, 95% CI [–0.68, –0.07]; Fig. 2d). Other pairwise comparisons are reported in the Supplementary Material (Table S3, see online supplementary material for a color version of this table).

TNT-related emotional change (post-ER to Post-TNT recall)

A 3 (*Material Type:* Negative-Watch, Negative-Reappraisal, Neutral-Watch) by 2 (*Rating Phase:* Post-ER, Post-TNT recall) repeated-measures ANOVA revealed a significant main effect of *Material Type* (F(2,86) = 249, $P < .001$, $\eta^2_p = .853$): participants reported higher ratings (i.e. more negative valence) for Negative-Watch materials than for Negative-Reappraisal and Neutral-Watch materials (both $P < .001$). The main effect of *Rating Phase* was not significant (F(1,43) = 0.172, $P = .680$, $\eta^2_p = .004$). Moreover, the *Material Type by Rating Phase* interaction was significant (F(2,86) = 34.4, $P < .001$, $\eta^2_p = .444$). Further simple effects analyses showed that, compared to Post-ER ratings, participants exhibited reduced negativity ratings for the Negative-Watch condition (t(43) = 5.073, $P < .001$, Bonferroni-corrected), but showed increased negativity ratings for the Negative-Reappraisal condition (t(43) = –3.358, $P = .025$, Bonferroni-corrected). The change for the Neutral-Watch condition was not significant (t(43) = –0.872, $P = 1.000$, Bonferroni-corrected).

Interestingly, these results indicate an emotional rebound during the TNT phase specifically for previously reappraised memories: their negativity ratings increased from post-ER to post-TNT recall (i.e. became more negative), whereas non-reappraised negative memories showed further negativity reduction over the same period.

We further calculated the valence change from post-ER to post-TNT recall by subtracting the valence rating during the post-TNT recall test from the post-ER rating (post-ER minus post-TNT recall). Thus, higher scores indicate larger reductions in negativity ratings associated with the TNT task. A 3 (*ER*: Negative-Watch, Negative-Reappraisal, and Neutral-Watch) × 2 (*TNT*: Think vs. No-Think) ANOVA only showed a main effect of *ER* (F(2,86) = 34.78, $P < .001$, $\eta^2_p = .447$). Post-hoc comparisons showed larger negativity reduction for Negative-Watch scenes (Mean = 0.38, SE = 0.07) than for Negative-Reappraisal scenes (mean = –0.30, SE = 0.09, $P < .001$, Bonferroni-corrected) or neutral scenes (mean = –0.02, SE = 0.02, $P < .001$, Bonferroni-corrected). Besides, the Negative-Reappraisal condition was associated with smaller negativity reduction than the neutral scenes ($P = .008$, Bonferroni-corrected). The *ER by TNT* interaction effect was not significant (F(2,86) = 0.58, $P = .560$, $\eta^2_p = .013$). However, the paired samples t-test showed larger negativity reduction for recalled Negative-Watch-NoThink memories than for Negative-Reappraisal-NoThink memories, t(43) = 6.98; $P < .001$, Cohen's $d = 1.05$, 95% CI [0.68, 1.42]). Other pairwise comparisons are reported in the Supplementary Material (Table S4, see online supplementary material for a color version of this table).

Exploratory analysis: individual differences in reappraisal success and memory control efficacy

An exploratory analysis was conducted to examine the relationship between emotion regulation success and memory control efficacy. The results revealed a significant negative correlation between participants' ER effect (defined as baseline ratings minus post-ER ratings under the Negative-Reappraisal condition) and their TNT effect (Think minus No-Think) on detail scores for recalling previously watched negative memories ($r = –0.307$, $P = .042$). In contrast, this correlation was not significant for previously reappraised negative memories ($r = –0.125$, $P = .419$). These findings suggest that participants who exhibited greater emotion regulation efficiency were less successful at forgetting details of unwanted memories. However, this relationship was specific to memories that had not undergone prior reappraisal.

ERP results

For brevity, we report results from the frontocentral N450, centro-parietal P300, and occipital LPP, as these are the most commonly examined ERPs in TNT and ER research. Other preregistered ERP analyses (i.e. left-parietal P300, right-parietal P300, frontocentral LPP, and centro-parietal LPP) and unregistered analyses (including an omnibus ANOVA with a location factor comprising three P300/LPP clusters) are provided in the Supplementary Material.

Frontocentral N450

The preregistered omnibus ANOVA only showed a significant *TNT* effect (F(1,35) = 6.52, $P = .015$, $\eta^2_p = .157$): As expected, No-Think trials were associated with larger (more negative) N450 than that in the Think trials, indicating enhanced cognitive control during retrieval suppression. The planned paired samples t-test showed comparable N450 amplitudes between Negative-Watch-NoThink and Negative-Reappraisal-NoThink conditions (t(35) = –1.18; $P = .247$, Cohen's $d = –0.20$, 95% CI [–0.53, 0.14], $BF_{01} = 2.95$).

Centro-parietal P300

The preregistered omnibus ANOVA showed that neither the main effect nor interaction effect (F(2,70) = 2.78, $P = .069$, $\eta^2_p = .074$; Fig. 3a) was significant. Planned paired samples t-test showed a larger P300 amplitude for the Negative-Reappraisal-NoThink condition than the Negative-Watch-NoThink condition (t(35) = 2.31; $P = .027$, Cohen's $d = 0.39$, 95% CI [0.04, 0.72]; Fig. 3b), suggesting that prior reappraisal increased participants' episodic recollections of unwanted memories. Other pairwise comparisons are reported in the Supplementary Material (Table S5, see online supplementary material for a color version of this table).

In addition, preregistered correlation analyses showed a significant and positive correlation between the P300 amplitude and negativity reduction from baseline to post-TNT recall in the Negative-Reappraisal-NoThink condition ($r = 0.38$, $P = .021$, 95% CI [0.06, 0.63]; Fig. 3c). That is, higher P300 amplitudes during the No-Think trials were associated with higher reductions in negative ratings.

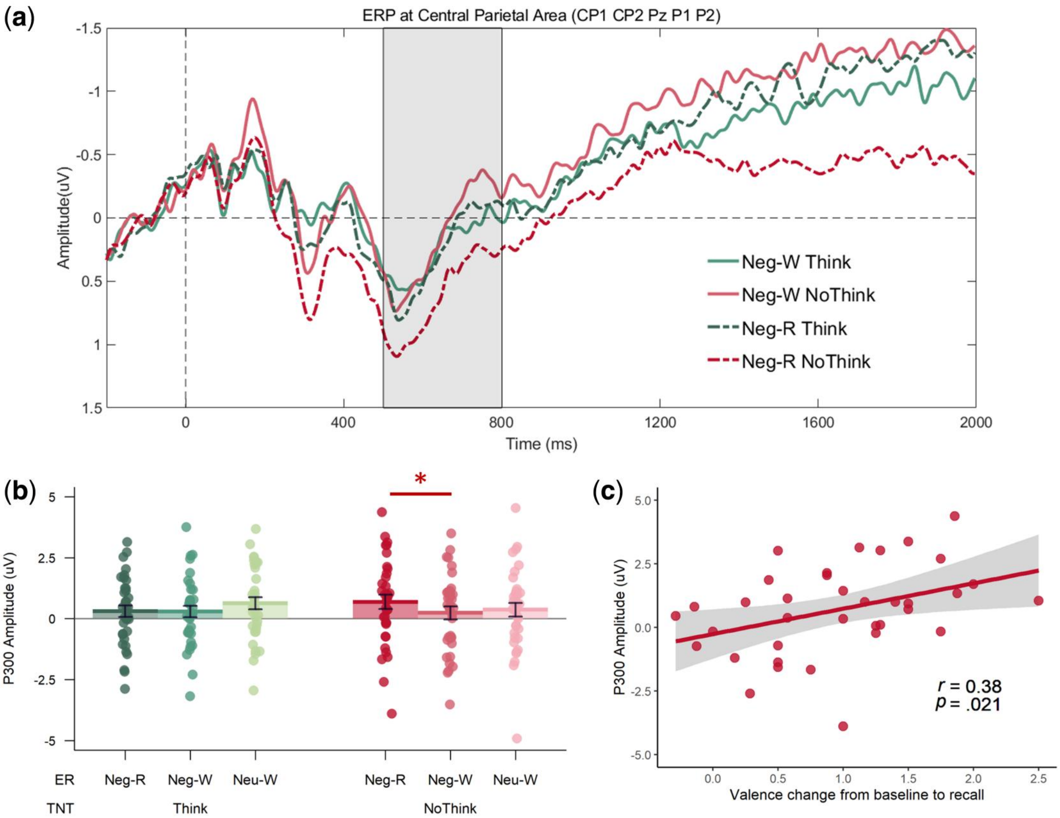

Figure 3 ERP results. (a) ERP waveforms at central parietal electrodes. (b) Mean amplitudes of the P300 component in six conditions. (c) A significant correlation between P300 amplitude and valence change from baseline to recall in Negative-Reappraisal-NoThink condition.

Note. The ERP data were averaged across electrodes of CP1, CP2, Pz, P1, and P2. The P300 was measured as mean amplitude within the time window of 500 to 800 ms post-cue presentation. Error bars represent the standard error of the mean. * indicates $P < .05$ for the preregistered pairwise comparison (*t*-test). The abbreviation "Neg-W" stands for "Negative-Watch," "Neg-R" stands for "Negative-Reappraisal," and "Neu-W" stands for "Neutral-Watch."

Non-preregistered correlation analysis also revealed a correlation between the P300 amplitude and negativity reduction from post-ER to post-TNT recall in the Negative-Reappraisal-NoThink condition ($r = 0.36$, $P = .029$, 95% CI [0.04, 0.62]) and Negative-Watch-NoThink condition ($r = 0.46$, $P = .005$, 95% CI [0.16, 0.69]).

Occipital LPP

The preregistered omnibus ANOVA showed a significant *TNT* effect ($F(1,35) = 5.10$, $P = .030$, $\eta^2_p = .127$): the mean amplitude of LPP was smaller in the No-Think than the Think condition. Planned paired samples *t*-test showed comparable LPP amplitudes between Negative-Watch-NoThink and Negative-Reappraisal-NoThink conditions ($t(35) = 0.19$; $P = .849$, Cohen's $d = 0.03$, 95% CI [–0.30, 0.36], $BF_{01} = 5.49$).

Discussion

Successful control of aversive memories and their involuntary intrusions can bring psychological benefits to people who experience traumatic events (Anderson and Hanslmayr 2014, Catarino *et al.* 2015). Here, we present new evidence highlighting that using cognitive reappraisal, an adaptive emotion regulation strategy, impacts subsequent memory control. Specifically, we found that during retrieval suppression of aversive memories, previous reappraisal was associated with larger P300 than non-reappraisal, which may suggest that reappraisal facilitates subsequent episodic recollections despite retrieval suppression attempts. Consistently, in the post-suppression recall, reappraisal facilitated recall of episodic details of aversive memories. Despite better episodic memories of these aversive scenes, reappraisal attenuated their negative emotional tones.

Implications for memory control

Our results did not support our preregistered hypothesis. First, we found a main TNT effect on N450 amplitudes. However, we observed no significant difference between two types of memories: those that had been simply watched before participants tried to suppress them, and those that had been reappraised before suppression. Larger frontal negativity has been associated with enhanced top-down inhibition during memory control (Bergström *et al.* 2009, Mecklinger *et al.* 2009, Chen *et al.* 2012, Zhang *et al.* 2016). Therefore, our results do not provide clear evidence that emotion regulation affects later inhibitory control. It is important to note that a null finding does not confirm that no effect exists. The absence of a significant difference could reflect limited statistical power. It might also reflect that the N450 component is not sensitive enough to detect any effect of reappraisal. Future studies with larger samples or more sensitive designs are needed to examine potential effect of reappraisal on subsequent inhibitory processing.

More importantly, we found that No-Think cues elicited larger P300 responses for reappraised aversive memories compared to those that were simply watched. The amplitude of the P300 component has been associated with the conscious recollection of episodic memories, with larger P300 amplitudes implicating more vivid recall and a richer recollection experience during retrieval (Bergström *et al.* 2009, Mecklinger *et al.* 2009, Depue *et al.* 2013, Hu *et al.* 2015). Based on this association, one possible interpretation is that retrieval suppression may be less successful after cognitive reappraisal than after watching. Separately, in the post-TNT cued recall test, participants recalled more details for No-Think aversive scenes that had been reappraised compared to those that had been simply watched. These behavioral and neural findings converge on the idea that reappraisal reduces the efficiency of retrieval suppression. However, alternative explanations remain possible, and caution is warranted when inferring cognitive processes from neural data.

One possible explanation for our findings is that reappraisal can enhance memory through elaboration (Richards *et al.* 2003, Hayes *et al.* 2010, Davis and Levine 2013). However, we only observed the reappraisal-induced memory enhancement effect in the No-Think conditions, not in the Think conditions, suggesting that reappraisal may specifically impact subsequent retrieval suppression. According to the nonmonotonic plasticity hypothesis (Depue *et al.* 2013, Ritvo *et al.* 2019, Wang *et al.* 2019), memories are more vulnerable to disruption and prone to forgetting when they are moderately activated. Therefore, we speculate that reappraisal would render these memories more vividly remembered, which could increase the difficulty of memory suppression and reduce the likelihood of forgetting (Richards *et al.* 2003, Hayes *et al.* 2010, Davis and Levine 2013).

Implications for emotion regulation

We observed the emotional effect of reappraisal during the recall of No-Think trials: participants rated the previously reappraised scenes less negative than those in the watch condition. Preregistered correlation analyses showed a significant positive correlation between P300 amplitude and the reduction in negative valence (from initial baseline to final recall) specifically for previously reappraised memories that participants were instructed to suppress ($r = 0.38$, $P = .021$). That is, higher P300 amplitudes were associated with greater overall emotional down-regulation from the initial rating (before any manipulation) to the final recall. One speculative interpretation is that the reduced negative tone following reappraisal may have weakened participants' motivation to suppress (Matthews *et al.* 2021), which could in turn relate to lower suppression success (Anderson and Hanslmayr 2014, Nørby 2015, Engen and Anderson 2018, Yao *et al.* 2021). However, this interpretation remains tentative, as the correlational nature of this finding precludes causal conclusions.

To isolate the contribution of the TNT phase itself, we examined negativity change from post-ER (immediately after reappraisal or passive viewing) to post-TNT recall. This measure revealed a striking dissociation: previously reappraised memories showed an emotional rebound (i.e. they became more negative than right after reappraisal), whereas unregulated intense memories showed further negativity reduction. These findings are consistent with the possibility that when negative memories have not been reframed through reappraisal, the TNT phase itself may contribute to further emotional down-regulation. However, alternative explanations (e.g. demand characteristics or repeated exposure effects) cannot be ruled out.

How can we reconcile the overall benefit of reappraisal (baseline-to-recall) with the rebound observed during the TNT phase? The answer lies in the initial effect of reappraisal: it produced a large reduction in negativity from baseline to post-ER, far exceeding the reduction in the watch condition. Even though reappraised memories then experienced a rebound during the TNT phase, their net change from baseline to final recall remained superior to that of watched memories. In other words, reappraisal provided an initial emotional buffer that outweighed the subsequent rebound.

These findings challenge a simplistic view of reappraisal as either uniformly beneficial or detrimental to memory control. Instead, they reveal a complex temporal dynamic: reappraisal initially neutralizes negative affect, but is also associated with larger P300 amplitudes (which have been linked to vivid retrieval) and a positive correlation with emotional improvement. One interpretation is that reappraisal makes memories more resistant to successful suppression, though this inference should be treated with caution. Reappraised memories are also more prone to emotional rebound during memory control attempts. Nevertheless, the net emotional outcome remains positive. These observations align with the view that reappraisal and retrieval suppression can serve complementary but sometimes opposing roles in shaping the affective and mnemonic fate of unwanted experiences (Richards *et al.* 2003, Hayes *et al.* 2010, Davis and Levine 2013).

Correlations between emotion regulation success and memory control efficacy

The exploratory correlation analysis revealed that participants with greater emotion regulation success (i.e. more effective down-regulation of negative valence via reappraisal) showed less subsequent forgetting of watched (non-reappraised) negative memories. This finding is intriguing because it runs counter to the intuitive prediction that better emotion regulation should facilitate memory control (Yang *et al.* 2021). One speculative interpretation is that individuals who are highly successful at cognitive reappraisal may habitually rely on this strategy and consequently have less practice or less motivation to engage in retrieval suppression. These two strategies are thought to operate at different stages of the emotion regulation process (Gross 2015, Bachfischer and Harris 2025). If this were the case, it could help explain why these individuals showed reduced suppression efficacy for watched memories.

Another possibility is that individuals with higher spontaneous reappraisal ability tend to habitually use this strategy to regulate their emotions, even when not explicitly instructed to do so. In the watch condition, where participants were asked to simply view negative scenes without reappraising, these high-ability individuals may have spontaneously engaged in reappraisal. This could be associated with a reduction in the negative emotional charge of the material. Consequently, they may have experienced less subjective distress, which could relate to lower motivation to suppress these memories during the subsequent memory control task (Nørby 2015, Engen and Anderson 2018). Such a pattern could help account for the observed negative correlation between reappraisal success and the TNT effect for watched memories.

In the reappraisal condition, by contrast, all participants were explicitly instructed to cognitively reappraise the negative scenes, regardless of their spontaneous reappraisal ability. This task-mandated reappraisal process likely altered the memory representations for all participants—for example, by adding semantic elaboration (making memories more detailed) and reducing negative emotional tone (Denny *et al.* 2015, Speer *et al.* 2021). These changes may have attenuated or overridden the influence of pre-existing individual differences in spontaneous reappraisal habits. Consequently, the relationship between trait-like emotion regulation ability and subsequent memory control efficacy was substantially weakened, consistent with the null correlation observed for reappraised memories.

However, these interpretations remain speculative. The analysis was exploratory (not preregistered), and the sample size was modest. Moreover, the observed correlation, while statistically significant, was only weak to moderate in magnitude ($r = -0.307$). Future studies with larger samples are needed to replicate this finding and to disentangle how individual differences in emotion regulation relate to distinct mechanisms of memory control.

Clinical implications

The research underscores the therapeutic potential of cognitive reappraisal for individuals struggling with distressing memories. By preserving valuable episodic details while reducing emotional distress, reappraisal facilitates the adaptive processing of negative experiences (Richards *et al.* 2003, Hayes *et al.* 2010, Davis and Levine 2013). As the saying goes, "*Take the lesson, leave the pain.*" Remembering negative experiences can be beneficial when they provide opportunities for growth and learning, particularly if their emotional impact is well-managed. Clinically, these findings may guide interventions aimed at improving emotional well-being by regulating unwanted memories, such as in trauma survivors or individuals with depression. Reappraisal strategies could help alleviate emotional burdens while enhancing the capacity to learn from past experiences.

Furthermore, reduced memory specificity, defined as an impaired ability to deliberately recollect specific details of past events, is a common feature across various mental health disorders such as depression and trauma-related disorders (Dalgleish and Hitchcock 2023). This is supported by a transdiagnostic meta-analysis demonstrating a significant difference (Hedges' $g = 0.86$) compared to non-diagnosed individuals (Barry *et al.* 2021). Reduced memory specificity is also shown to associate with "generalized cognitive patterns" characterizing emotional disorders, such as rumination in depression (Watkins and Teasdale 2001, Raes *et al.* 2008). Interventions training individuals to focus on concrete, detailed cognition while reducing generalized context-based processing—such as mindfulness-based cognitive therapy—improve both memory specificity and rumination (Piet and Hougaard 2011, Hitchcock *et al.* 2022). Cognitive reappraisal training thus holds potential for ameliorating memory deficits and clinical symptoms in affective disorders, and further investigation into this relationship may inform more effective therapeutic approaches for memory-related psychopathological conditions.

Limitations and future directions

While the current findings provide valuable insights into the impact of ER on MC, future studies should employ diverse methodologies (e. g. different populations, experimental designs, materials) to test the validity and replicability of these results.

First, the participants in this study were healthy adults with no history of neurological or psychiatric disorders. To gain insights into therapeutic applications, future research should explore how emotion regulation aids in the voluntary control of unwanted memories in populations with memory control deficits, such as those with depression or post-traumatic stress disorder (Anderson and Hanslmayr 2014, Catarino *et al.* 2015, Nørby 2018).

Second, the present study experienced a relatively high attrition rate due to stringent exclusion criteria, including low task compliance and excessive EEG artifacts. While these criteria ensure data quality and adherence to task instructions, the resulting reduction in sample size may have limited statistical power, thereby increasing the likelihood of Type II error and reducing the generalizability of the findings. Future studies with larger samples are needed to mitigate this issue and test the robustness of our results. Relatedly, we acknowledge that many of our speculations and interpretations remain tentative, as they were based on *t*-test comparisons rather than more rigorous ANOVA models. Moreover, the correlational results were derived from exploratory analyses, and thus their robustness requires further validation.

Third, participants in this study reappraised each negative scene only once. While this effectively reduces negative valence, it may not fully address strong aversive emotions. Investigating multiple reappraisal attempts, akin to repeated sessions in clinical settings, could provide a further understanding of their impact on memory control (Hofmann *et al.* 2012, Denny 2020).

Another limitation is the use of emotional scene pictures from the IAPS, which may lack the ecological validity needed to adequately simulate real-life unwanted memories. Future research should use more self-relevant materials (e.g. participants' own autobiographical memories) to test the replicability of the present findings. Additionally, it should be noted that each experimental condition contained only eight stimulus pairings, which may limit statistical power. Nevertheless, the counterbalancing procedure employed in this study helps mitigate concerns regarding stimulus-specific confounding.

Finally, it is crucial to investigate the long-term effects of emotion regulation on memory control. While our study had a short interval between the ER task and the TNT task, recent research shows that memory representations can be updated through cognitive reappraisal after a 24-h consolidation period (Speer *et al.* 2021). Therefore, it would be intriguing to examine whether emotion regulation may have a lasting impact on subsequent memory control over an extended period.

Conclusion

In closing, our findings underscore the dual benefits of cognitive reappraisal, showing that it not only preserves (and even enhances) the episodic accuracy of negative memories but also reduces their emotional impact during recall. While the results did not fully align with our initial hypotheses that reappraisal would ease memory control, they offer nuanced insights into the interaction between ER and MC. This highlights the intricate relationship between ER and MC, emphasizing the need for further research to investigate its neural mechanisms, clinical applications, and long-term effects.

Author contributions

Hui Xie (Conceptualization [equal], Data curation [lead], Formal analysis [equal], Investigation [lead], Methodology [equal], Writing—original draft [lead], Writing—review & editing [equal]), Xuanyi Lin (Data curation [supporting], Formal analysis [equal], Investigation [supporting], Software

[lead], Visualization [lead], Writing—original draft [supporting]), Jinxiao Zhang (Methodology [supporting], Writing—review & editing [supporting]), Dandan Zhang (Methodology [supporting], Resources [supporting]), James J. Gross (Funding acquisition [supporting], Writing—review & editing [supporting]), and Xiaoqing Hu (Conceptualization [equal], Funding acquisition [lead], Resources [lead], Supervision [lead], Writing—original draft [supporting], Writing—review & editing [lead])

Supplementary material

Supplementary material is available at *SCAN* online.

Conflicts of interest

Authors declare no conflicts of interest in relation to the subject of this study.

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Data availability

The data and code of this study would be available upon reasonable request to the corresponding author Xiaoqing Hu (xiaoqinghu@hku.hk).

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