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Forgetting positive social feedback is difficult: ERP evidence in a directed forgetting paradigm

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Abstract

Voluntary forgetting of unwanted memories is an adaptive cognitive function. However, it remains unknown how voluntary forgetting of unwanted social feedback may influence subsequent memories and evaluations, and what the underlying neurocognitive processes are. Here, we presented participants with peer photos together with feedback indicating social acceptance or rejection, followed by "remember" or "forget" instructive cues, while electroencephalograms were recorded during the experiment. We examined the Directed Forgetting (DF) effect in a recognition memory test, and tested participants' explicit and implicit attitudes toward the peers using a social evaluation task and an affect misattribution procedure (AMP). Both the memory test and the AMP were examined immediately and 3 days after the DF task so to estimate both the instant and the long-term effects of memory control. Behaviorally, immediate memory test showed smaller DF effect for positive than negative social feedback, which suggests that forgetting positive social feedback was more difficult than forgetting negative social feedback. Regarding the ERP results, although participants showed comparable frontal N2 amplitudes (reflecting inhibitory control efforts) following the instruction of forgetting positive and negative social feedback, positive feedback elicited larger late positive potential (LPP) amplitudes than negative feedback during initial encoding phase, suggesting an encoding bias for positive self-relevant information. Intriguingly, voluntary efforts to forget negative social feedback enhanced people's explicit and implicit evaluations toward the feedback senders. These findings provide new evidence for the adaptive function of memory control, which broadens the influence of voluntary forgetting in the context of social interaction and social evaluation.

KEYWORDS
affect misattribution procedure, directed forgetting, event-related potential, social acceptance, social evaluation, social rejection

1 | INTRODUCTION

Human beings are social animals and thrive in relationships with others. People socialize and interact with each other on a daily basis, and thus, receive a considerable amount of social feedback information. Similar to nonsocial information, not all social information is welcome (Nørby, 2018). It would be desirable for people to intentionally control what they remember and forget, so that they can flexibly adjust their social behaviors according to certain social feedback. Furthermore, negative social feedback such as social rejection that threatens people's social connections can induce mental distress known as *social pain* (Eisenberger, 2015). Because memory plays a critical role in shaping people's emotional states and feelings (Engen et al., 2016), suppressing unwanted memories of negative social feedback is important for maintaining mental health among those who are vulnerable to negative social feedback and suffering from persistent social pain (e.g., individuals with social phobia/anxiety and depression; Holt-Lunstad et al., 2010).

Over the past decades, scores of studies have demonstrated that actively suppressing unwanted memories by engaging the inhibitory control mechanisms associated with the dorsolateral prefrontal cortex (DLPFC) successfully facilitate forgetting, a cognitive procedure known as *voluntary/intentional forgetting* (for a review, see Anderson & Hanslmayr, 2014). Moreover, voluntary forgetting efforts can not only influence the contents of memory (through down-regulating neural activations of the hippocampus), but also ameliorate individuals' affective reactions (through down-regulating neural activations of the amygdala) (Gagnepain et al., 2017). Remembering positive and forgetting negative experiences benefits psychological well-being over a person's life span (Charles et al., 2003), and an efficient memory control system associated with voluntary forgetting is critical to maintain emotional health (Engen & Anderson, 2018). However, most previous studies on voluntary forgetting have used nonsocial materials (such as emotional words and images); thus, it remains unknown whether people can control social memories that are obtained during interpersonal activities. Because a large proportion of unwanted memories originate in social contexts, examining voluntary forgetting of social feedback bears high ecological validity. Moreover, this study will also have significant implications for treatment of affective disorders such as social anxiety, because socially anxious people are found to have maladaptive memories of social information such as enhanced memory for self-threatening information (Glazier & Alden, 2017; Zengel et al., 2015).

Memory control can operate during either the encoding or the retrieval stage (Anderson & Hanslmayr, 2014). The item-method directed forgetting (DF) paradigm is widely used to investigate memory control during encoding, wherein participants are instructed to remember certain stimuli and forget the others based on "remember" or "forget" instructive cues (Bjork, 1989). The DF effect is defined as better subsequent memory of to-be-remembered (TBR) stimuli than to-be-forgotten (TBF) stimuli. One of the frequently mentioned cognitive mechanisms for the item-method DF effect is the selective rehearsal theory (Bjork, 1989; for a review, see Anderson & Hanslmayr, 2014). According to this theory, TBR items were remembered due to selective rehearsal, whereas TBF items were passively forgotten due to lack of rehearsal. However, the key role of frontal-parietal regions in directed forgetting has been widely documented with the prosperity of neuroimaging studies; these findings support an inhibitory control mechanism, that is, forgetting is a process including active limitation of unwanted information during encoding period (Bastin et al., 2012; Gamboa et al., 2018; Nowicka et al., 2010; Rizio & Dennis, 2013; Wylie et al., 2008; Xie et al., 2020). Evidence from event-related potential (ERP) studies also consistently shows that "forget" instructions elicit a larger N2 component than "remember" instructions, which possibly reflects cognitive control efforts (Brandt et al., 2013; Cheng et al., 2012; Gao et al., 2016; Hauswald et al., 2010; Hsieh et al., 2009; Liu et al., 2017; Paz-Caballero et al., 2004; Schindler & Kissler, 2018; van Hooff & Ford, 2011; Xie et al., 2018; Yang et al., 2012). To summarize, using nonsocial materials, studies have robustly demonstrated an important role of inhibitory control in voluntary forgetting of unwanted information during encoding stage.

The first goal of the present study is to introduce social information into the field of voluntary forgetting. To achieve this, the social judgment paradigm (SJP, Somerville et al., 2006) is employed to create a social feedback situation with high ecological validity. In this paradigm, participants are instructed to believe that their photos have been evaluated by a panel of peers. They are then presented with positive or negative peer feedback indicating social acceptance or social rejection. To investigate voluntary memory control of social feedback, this study incorporated the SJP into a DF task: after participants were presented with peer feedback under the cover story, they were required to remember or forget the feedback according to the cues provided. Subsequently, participants' memory of social feedback was measured in a recognition memory test. Evidence from social cognition has shown that positive social feedback is consistent with people's internal motivation of self-protection/affirmation (Sedikides & Green, 2004; Walker et al., 2003), whereas negative social feedback is self-threatening and tends to be selectively forgotten (a phenomenon known as *mnemic neglect*; for a review, see Sedikides et al., 2016). Accordingly, we hypothesized that participants may have more difficulty in forgetting positive social feedback than negative social feedback, resulting in a smaller DF effect for positive, compared to negative, condition.

In addition to the behavioral DF effect, this study also investigates the underlying neurocognitive mechanisms using the ERP technique. The DF task can be divided into two stages, namely the information encoding stage prior to the presentation of the instructive cue, and the memory control stage following the cue presentation (Xie et al., 2018). The high temporal resolution of the ERP technique makes it a suitable tool to investigate the neural dynamics during the two distinct stages. In the information encoding stage, the study focuses on the late positive potential (LPP), which has been associated with elaborative or integrative processing of emotional materials in previous emotional DF studies (Bailey & Chapman, 2012; Hauswald et al., 2010; Xie et al., 2018; Yang et al., 2012). Numerous previous studies using nonsocial materials (e.g., emotional words or pictures) have found comparable or even larger LPP amplitudes in negative, compared to positive, conditions (e.g., Schupp et al., 2000; for a review, see Hajcak et al., 2010). However, recent studies have demonstrated that the LPP amplitudes seem to show a different pattern when emotions are examined in social contexts, that is, larger LPP amplitudes were found following positive than negative social information (Bublatzky et al., 2014; Funkhouser et al., 2020; Gu et al., 2020). For instance, Funkhouser et al. (2020) observed in an Island Getaway Task that participants showed larger LPP amplitudes for positive, compared to negative, social feedback given by peers. Similarly, our group used the Social Judgment Paradigm and found in individuals with a low but not high level of social anxiety that a positive social judgment evoked larger LPP amplitudes than a negative social judgment did (Gu et al., 2020). This LPP phenomenon might be explained by the mnemic neglect effect (Pinter et al., 2011), which proposes that people prefer to allocate abundant cognitive resources to elaborately integrate self-affirming information at the cost of insufficient memory encoding of self-threatening information. According to the ERP findings in social contexts, this study predicts that positive social feedback will elicit a larger LPP than negative social feedback during the encoding stage.

In the memory control stage, this study focuses mainly on two ERP components that have been associated with two distinct processes during directed forgetting: the forget-cue-evoked N2 (with amplitudes peaking at the middle frontal area) and the remember-cue-evoked LPP (with amplitudes peaking at the parietal area). The “forget” cue usually evokes larger N2 amplitudes (more negative-going potentials) than the “remember” cue, which reflects the inhibitory control process that truncates the encoding of unwanted information (Gao et al., 2016; Hsieh et al., 2009; Patrick et al., 2015; Xie et al., 2018; Yang et al., 2012). In contrast, the “remember” cue usually elicits larger LPP amplitudes than the “forget” cue, which indicates selective rehearsal or sustained processing of TBR information (Bailey & Chapman, 2012; Cheng et al., 2012; Hauswald et al., 2010; Hsieh et al., 2009; Paz-Caballero et al., 2004; Schindler & Kissler, 2018; van Hooff & Ford, 2011). It has been demonstrated that both motivated inhibition and reduced selected rehearsal contribute to successful directed forgetting (Hauswald et al., 2010). Moreover, a recent EEG study has further revealed that these two processes can be distinguished in EEG data using different frequency bands and temporal windows (Fellner et al., 2020). Regarding the emotional effect on DF and the associated neural correlates, previous studies using nonsocial materials demonstrated enhanced frontal activities elicited by forget-cues when participants forgot negative versus neutral memories, suggesting that forgetting emotional memories requires larger cognitive efforts/resources (Nowicka et al., 2010; Yang et al., 2012). Since previous literature has not directly compared the neural correlates associated with the DF effect between positive and negative materials, we tentatively propose two possible hypotheses and associated ERP patterns. First, we expect larger forget-cue-evoked N2 amplitudes for positive than negative social feedback, since better encoded information needs larger cognitive control efforts to inhibit (Houghton & Tipper, 1996; Nowicka et al., 2010; Yang et al., 2012). Alternatively, the inhibition process would be influenced by motivation. Because participants usually show decreased internal motivation to forget positive social feedback (Sedikides & Green, 2004; Sedikides et al., 2016; Walker et al., 2003), smaller N2 amplitudes would be elicited when participants forget positive, compared with negative, social feedback. With regard to the LPP amplitudes evoked by remember-cues, we predict smaller LPP for positive, compared with negative, TBR social feedback. This is because positive social feedback has been sufficiently encoded during the previous stage, thus, it no longer needs further elaborative processing during selective rehearsal.

The second goal of the current study is to examine whether voluntary forgetting of unwanted social feedback can affect people's emotional attitudes toward the feedback providers. With nonsocial materials, it has been established that controlling unwanted negative memories could simultaneously downregulate the accompanying emotional responses, evidenced by top-down regulation of both the hippocampus/medial temporal lobe and the amygdala (Engen & Anderson, 2018; Gagnepain et al., 2017; Hu et al., 2017). Employing the DF task, Vivas et al. (2016) found that voluntary forgetting resulted in subsequent emotional devaluation of unwanted memories. Therefore, we aimed to examine whether memory control could also influence people's emotional attitudes in social contexts. Specifically, a social evaluation task and an affect misattribution procedure (AMP, Payne et al., 2005) was employed to investigate participants' explicit and implicit attitudes toward peers who gave either positive or negative social feedback. In the social evaluation task, participants' attitudes toward peers are explicitly revealed by self-reported decisions on whether or not they like the peers. In the AMP, participants may misattribute their affective reactions from the primes (i.e., social feedbacks) to the subsequent neutral targets. Thus, affective ratings of the targets can be used to indicate participants' implicit evaluations of the primes (for a review, see Payne & Lundberg, 2014). In accordance with previous findings (Gagnepain et al., 2017; Vivas et al., 2016), we expect that voluntary forgetting of social feedback will influence participants' attitudes toward peers. Specifically, we predict that forgetting negative social feedback will result in less negative evaluation toward the rejecters.

The third goal of the current study is to investigate the time course of the DF effect of social feedback. It is well-known that episodic memory with different durations (e.g., short vs. long term) are based on nonoverlapping neural networks (Kesner & Hunsaker, 2010). Earlier studies using nonsocial materials such as words have observed the DF effect after a long interval (e.g., 1 week; MacLeod, 1975, 1989). According to the Ebbinghaus forgetting curve (Ebbinghaus, 1885), memory performance might decrease to a low level after 3 days. Therefore, in addition to the classical test soon after the social judgment and directed forgetting (SJ-DF) task, this study also tested participants 3 days after the task to investigate the short- and long-term effects of memory control of social feedback. We expect that while in the short-term participants can intentionally remember/forget negative social feedback due to the remember/forget cues, they will forget negative feedback regardless of the instruction in the long term because forgetting negative social feedback is consistent with people's internal motivation of self-protection (Sedikides & Green, 2004; Sedikides et al., 2016; Walker et al., 2003). In line with this prediction, the stronger DF effect on negative social feedback (compared to positive social feedback) might disappear in the 3-day delayed test.

2 | METHOD

2.1 | Participants

A total of 40 right-handed college students were recruited from Shenzhen University as paid participants. Five students participated in the behavior-only experiment as pilots, and 35 students participated in the formal experiment. Two students did not complete the whole experimental procedure, leaving 38 participants in the behavioral data analyses (21 males; mean ± standard deviation = 22.1 ± 2.3 y). Four additional participants from the EEG experiment were excluded because of excessive artifacts, leaving 29 students in the EEG analyses (16 males; 21.9 ± 2.4 y). All participants reported to have normal or corrected-to-normal vision and have no history of neurological or psychiatric disorders. They never caught a cold those days and slept well at night before the experiment. We used the Beck Depression Inventory Second Edition (BDI-II; Beck et al., 1996) to assess participants' depressive symptoms, all participants reported scores lower than 13 (indicating minimal depressive symptoms, mean ± standard deviation = 6.1 ± 4.2). All participants signed informed consents prior to the experiment. The study protocol was reviewed and approved by the Ethics Committee of Shenzhen University.

TABLE 1 Attractiveness and favorability of facial photos rated at a 5-point scale (mean ± standard deviation)

Condition	Attractiveness	Favorability
Positive-remember	2.52 ± 0.50	2.61 ± 0.45
Positive-forget	2.50 ± 0.52	2.61 ± 0.52
Negative-remember	2.54 ± 0.45	2.60 ± 0.47
Negative-forget	2.52 ± 0.52	2.62 ± 0.48

2.2 | Experimental design and stimuli

We employed a two (valence of social feedback: positive vs. negative) × two (instructive cue: remember vs. forget) within-subject design in this study. A total of 160 front identity photos of young adults were used as materials, with equal numbers of females and males. Each photo was standardized with respect to the size, luminance, and background color using Photoshop software. An additional 28 volunteers (14 males, 22.3 ± 1.9 y) rated the attractiveness and favorability of each face on a 5-point scale (1 = low; 5 = high). These two features were counterbalanced during photo allocation across the four conditions ($Fs < 1$; Table 1).

2.3 | Procedure

2.3.1 | The preparation stage and cover story

Approximately 1 week prior to the experiment, participants were told that they would take part in a study on first impression evaluation and were asked to send an identity photograph of themselves to the researcher. Participants were told that their photograph would be sent to a panel of unfamiliar peers to judge whether they liked the participants based on the first impression.

2.3.2 | Social judgment and directed forgetting task

We presented peers' photos with their evaluative feedback to the participants, after which participants were instructed to either remember or forget the social feedback according to the cues. A total of 160 photos were presented sequentially in a random order and each photo was presented only once. As shown in Figure 1a, the photo was presented for

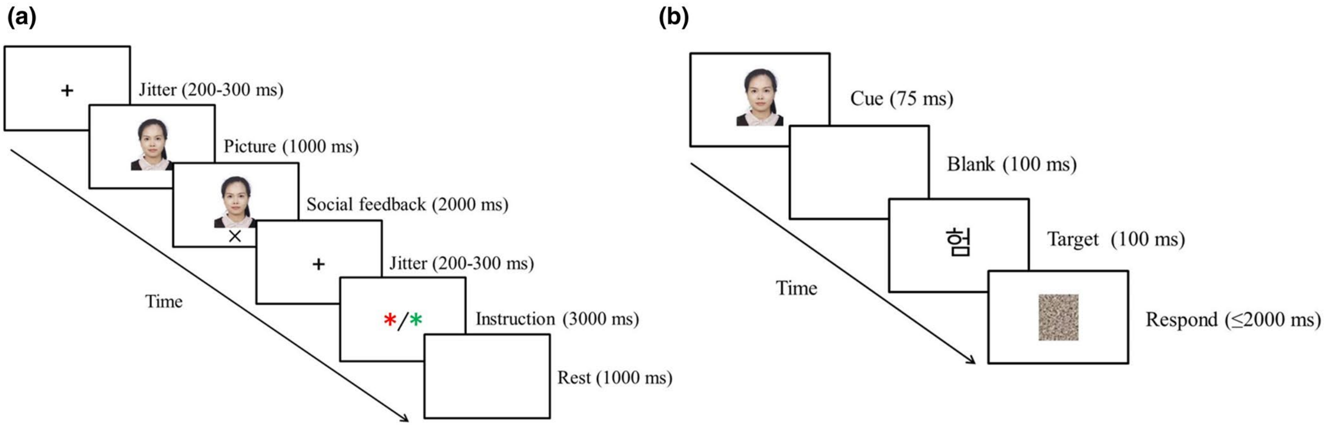

FIGURE 1 Experiment programs. (a) Illustration of one trial in the social judgment and directed forgetting task. (b) Illustration of one trial in the affect misattribution procedure

1 s followed by a tick mark (√) or a cross mark (×) presented under the photo for 2 s (see also Qi et al., 2017). Participants were told that the tick mark indicated positive feedback (i.e., the peer liked them) and the cross mark indicated negative feedback (i.e., the peer disliked them). The probability of positive/negative feedback was equal. After feedback presentation, a 3-s instructive cue was presented. The cue was an asterisk printed in either green or red (see also Xie et al., 2018, 2020), instructing participants to remember (green) or to forget (red) the previously presented face and the associated social feedback (remember vs. forget = 50% vs. 50%). There were four within-subject conditions in this task (i.e., positive-remember, positive-forget, negative-remember, and negative-forget), with 40 trials per condition. Trials from different conditions were mixed and presented in a random order. Blocks were separated by self-paced breaks. The EEG data were continuously recorded during this task.

2.3.3 | Immediate test

After the SJ-DF task, participants took a 3-min break and then proceeded to the immediate test in which an explicit memory test and an implicit AMP were performed. The materials (160 photos) were divided into two subsets, with one subset used for the recognition memory test and the other for the AMP. The subsets used for the two tasks were counterbalanced across participants. In the explicit memory recall test, a subset of materials (80 photos) used in the SJ-DF task were presented in a random order, with 20 trials in each condition. Each trial began with the photo presentation and participants were required to recall the feedback given by the peer (i.e., he/she liked or disliked me) within 2 s, irrespective of the "remember/forget" instructions. In the AMP, the other 80 photos from the SJ-DF task were randomly presented and each photo was presented only once. There were 20 trials in each condition. As shown in Figure 1b, each trial began with the presentation of a photo for 75 ms, followed by a blank screen for 100 ms. Then, a Korean character were presented for 100 ms (none of participants were familiar with this language). After the Korean character, a "noisy picture" appeared as a mask and participants were required to judge whether the Korean character indicated a pleasant or unpleasant meaning within 2 s while avoiding the influence of the previously presented photo. The order of the explicit recognition memory test and the AMP was counterbalanced across participants.

2.3.4 | Three-day delayed test

After an interval of 3 days, participants were invited to the laboratory again and performed the explicit recognition memory test and the AMP for the second time. Materials for the two tasks were swapped, that is, the photos that were presented in the immediate recognition memory test served as materials in the AMP this time, and vice versa. The order of the explicit recall test and the AMP was the same as in the immediate tests. One hour after the two tests, participants performed a social evaluation task, in which they indicated whether they liked the person or not within 2 s. The task used the same 80 photos as in the explicit memory test, with 20 trials in each condition.

2.4 | EEG recording and analysis

Continuous EEGs were recorded during the SJ-DF task with the online reference against the CPz electrode using a 64-channel wireless EEG amplifier with a sampling rate of 250 Hz (NeuSen. W64, Neuracle, Changzhou, China). Electrode impedances were kept below 10 kΩ. Data were re-referenced offline to the average of the left and right mastoids (which may result in a more midline centered topography than average reference), followed by ocular artifacts rejection using the independent component analysis procedure implemented in the Brain Products software (BrainVision Analyzer 2.1).

EEG data were offline filtered (0.1–30 Hz with a slope of 24 dB/oct) and segmented into epochs (−200–800ms) according to the onset of feedback and the instructive cues. Trials contaminated with significant artifacts (peak-to-peak deflection exceeded ± 100 μV) were excluded from further analyses. All epochs were baseline-corrected with respect to the mean voltage over the 200 ms preceding the onset of stimuli, followed by averaging within each condition. The number of clean trials used for ERP averaging is presented in Table 2.

For the feedback-evoked ERP, we analyzed the average amplitudes of the LPP component. The time windows for ERP analyses were decided a priori based on previous related studies. We calculated the LPP amplitude as the average amplitude at the electrode sites of P3, P4, and Pz between 500 and 800 ms after feedback onset (Langeslag & van Strien, 2013; Lapinskaya et al., 2016; Mollison & Curran, 2012). For the instruction-evoked ERP, we analyzed the average amplitudes of the N2 and the LPP components. In particular, the N2 amplitude was calculated as the average amplitude at the electrode sites of F1, F2, and Fz between 300 and 400 ms after the onset of instructive cues (Clayson & Larson, 2013; Xue et al., 2013). The LPP amplitude was calculated as the average amplitude at the electrode sites of P3, P4, and Pz between 300 and 600 ms after cue onset (Katyal et al., 2020; Schienle et al., 2020).

2.5 | Statistics

Statistical analysis was performed using SPSS Statistics 22.0 (IBM, Somers, USA). Descriptive data were presented as mean ± standard deviations, unless otherwise mentioned. The significance level was set at 0.05. Repeated-measures analyses of variance (ANOVA) was performed on behavioral and ERP measurements, with valence of social feedback (positive vs. negative) and instruction (remember vs. forget) as within-subject factors. Two-tailed Pearson's *r* correlation was performed between ERP measures during the SJ-DF task (i.e., amplitudes of feedback-evoked LPP, instruction-evoked N2 and LPP) and the behavioral indicators (i.e., recall accuracy in the recognition memory tests and the positive judgment rate in the AMP and social evaluation task). Holm's stepwise method was used for the correction of multiple comparisons. For the sake of concision, only significant correlations were reported in the results.

TABLE 2 Number of clean trials for ERP averaging (mean ± standard deviation)

Condition	Feedback-evoked	Instruction-evoked	
		Remember	Forget
Positive	71.8 ± 4.3	34.9 ± 2.2	35.2 ± 2.1
Negative	72.2 ± 3.9	35.3 ± 2.0	35.1 ± 2.1

3 | RESULTS

3.1 | Behavioral data

3.1.1 | Explicit recognition memory test

We examine the recognition accuracy in the explicit memory test. Here, the recognition accuracy for each condition was measured as the proportion of correctly responded trials. In the immediate test phase, the main effect of valence was significant ($F(1,37) = 6.0$, $p = .019$, $\eta_p^2 = 0.139$): participants recognized more positive (58.7 ± 13.5%) than negative (50.4 ± 14.3%) social feedback. The main effect of instruction was significant ($F(1,37) = 9.2$, $p = .004$, $\eta_p^2 = 0.198$; TBR vs. TBF: 57.0 ± 13.2% vs. 52.0 ± 14.6%). We also found a significant interaction between valence and instruction ($F(1,37) = 5.4$, $p = .025$, $\eta_p^2 = 0.128$; Figure 2a). For negative social feedback, participants recalled more TBR than TBF items ($F(1,37) = 14.6$, $p < .001$, $\eta_p^2 = 0.283$). However, this DF effect was not significant for positive social feedback ($F(1,37) = 0.7$, $p = .394$, $\eta_p^2 = 0.020$). Besides, participants had higher accuracy for positive, compared with negative, TBF items ($F(1,37) = 8.4$, $p = .006$, $\eta_p^2 = 0.184$), while this valence effect was not significant for TBR items ($F(1,37) = 2.4$, $p = .130$, $\eta_p^2 = 0.061$). In the 3-day delayed test, however, neither main effects ($Fs < 1$, $p > .05$) nor interactive effect ($F(1,37) = 1.5$, $p = .225$, $\eta_p^2 = 0.040$) was significant. Descriptive data for each condition is presented in Table 3.

To compare the recognition accuracy in the two test phases, we conducted a three-way repeated-measures ANOVA, with valence of social feedback, instruction, and time (immediate vs. delayed) as three factors. Among the effects associated with the factor *time*, the main effect is significant ($F(1,37) = 9.7$, $p = .004$, $\eta_p^2 = 0.208$; immediate vs. delayed test: 54.5 ± 13.9% vs. 50.3 ± 16.9%). The interaction of instruction by time was also significant ($F(1,37) = 8.0$, $p = .008$, $\eta_p^2 = 0.178$): participants recognized more TBR items in the immediate test than in the delayed test ($F(1,37) = 14.1$, $p = .001$, $\eta_p^2 = 0.275$), whereas this difference was not significant for TBF items ($F(1,37) < 1$, $p = .558$, $\eta_p^2 = 0.009$). Thus, the results of explicit memory tests indicate that the DF effect was significant only for negative social feedback in the immediate test.

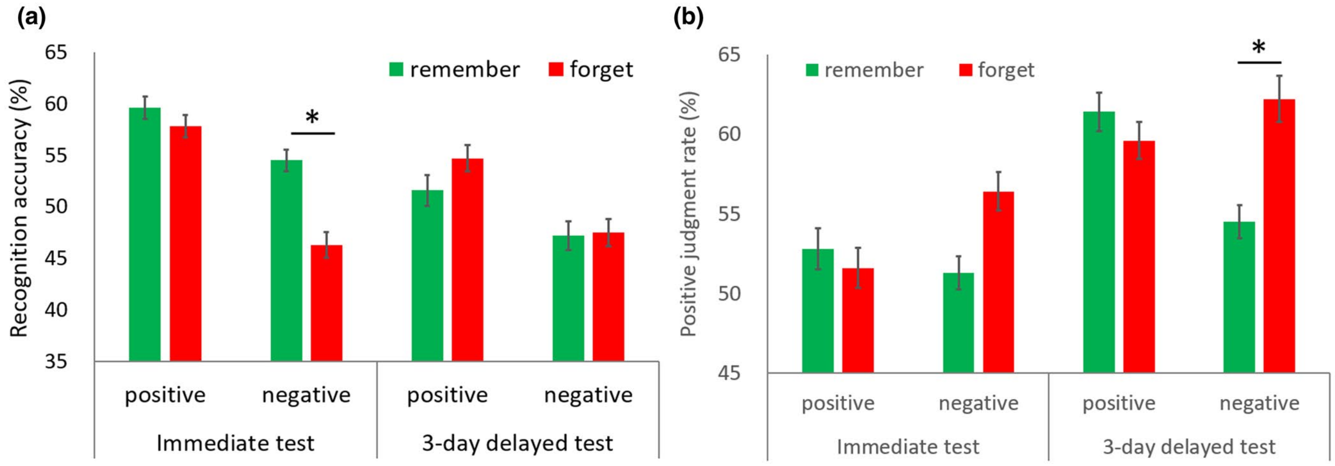

FIGURE 2 Main behavioral results. (a) Recall accuracy in the explicit memory test. (b) Positive judgment rate in the affect misattribution procedure. Bars represent ± standard error of the mean. *$p < .05$

TABLE 3 The recall accuracy (ACC) in the recognition memory test and the positive judgment rate (PJR) in the affect misattribution procedure (mean ± standard deviation)

	ACC (%)		PJR (%)	
Condition	Immediate	Delayed	Immediate	Delayed
Positive-remember	59.6 ± 13.3	51.6 ± 18.4	52.8 ± 16.1	61.5 ± 14.9
Positive-forget	57.8 ± 13.6	54.8 ± 15.4	51.6 ± 15.7	59.6 ± 14.2
Negative-remember	54.5 ± 13.0	47.2 ± 17.4	51.3 ± 12.8	54.5 ± 12.9
Negative-forget	46.3 ± 15.6	47.5 ± 16.3	56.4 ± 14.6	62.2 ± 17.6

Since the higher accuracy in positive conditions could simply resulted from positive response bias, we calculated participants' positive response proportion in the two explicit tests. Results showed that participants responded with positive judgment in 52.9 ± 10.2% trials during the immediate test and in 52.2 ± 14.0% trials during the delayed test; no difference was found between these two rates and the value of 50% (one-sample $t \leq 1.786$, $p \geq .082$). Therefore, no response bias was found in the recognition memory test.

3.1.2 | Affect misattribution procedure

We measured the AMP effect using positive judgment rate; a larger value indicates a more positive implicit evaluation toward peers. In the immediate AMP test, neither the main effects ($Fs < 1$, $p > .05$) nor the interaction effect ($F(1,37) = 3.1$, $p = .086$, $\eta_p^2 = 0.078$) was significant. Whereas in the delayed AMP, we found a significant interaction between valence and instruction ($F(1,37) = 9.8$, $p = .003$, $\eta_p^2 = 0.209$; Figure 2b) although the main effect of valence ($F(1,37) = 1.4$, $p = .246$, $\eta_p^2 = 0.036$) and instruction were not significant ($F(1,37) = 3.5$, $p = .070$, $\eta_p^2 = 0.086$). The simple effect analyses revealed that for negative social feedback, the positive judgment rate was significantly lower for TBR than TBF items ($F(1,37) = 9.1$, $p = .005$, $\eta_p^2 = 0.197$), whereas the difference between TBR and TBF items was not significant for positive social feedback ($F(1,37) = 1.1$, $p = .303$, $\eta_p^2 = 0.029$). Descriptive data for each condition is presented in Table 3.

We then conducted a three-way repeated-measures ANOVA to compare the results between the two AMP tests. Among the effects associated with the factor *time*, we only found a significant main effect ($F(1,37) = 11.3$, $p = .002$, $\eta_p^2 = 0.234$); the positive judgment rate was higher in the delayed test (59.4 ± 14.9%) compared to the immediate test (53.0 ± 14.8%). In summary, participants' implicit emotional attitudes toward peers improved after an interval of 3 days only when they were instructed to forget the negative social feedback from those peers.

3.1.3 | Social evaluation task

To determine how memory of social feedback influenced social evaluations, we divided the faces into four conditions according to participants' performance on the delayed recall test (i.e., positive/negative-remembered and positive/negative-forgotten) and performed a repeated-measures ANOVA on the positive judgment rates in the social evaluation task, with valence of social feedback and memory outcome (remembered vs. forgotten) as two within-subject factors. The number of trials is 21.3 ± 6.1, 18.7 ± 6.1, 18.9 ± 6.3, and 21.1 ± 6.3 trials in the positive-remembered, positive-forgotten, negative-remembered, and negative-forgotten condition.

The interaction between valence of social feedback and memory outcome was significant (F(1,37) = 19.5, p < .001, η_p^2 = 0.345). For faces associated with positive social feedback, the positive judgment rate was higher for remembered than for forgotten items (F(1,37) = 13.5, p =.001, η_p^2 = 0.268; 47.4 ± 22.5% vs. 32.4 ± 23.3%). However, this effect was reversed for faces associated with negative social feedback, that is, the positive judgment rate was lower for remembered than for forgotten items (F(1,37) = 21.1, p < .001, η_p^2 = 0.364; 35.9 ± 22.6% vs. 50.9 ± 19.5%). This finding indicated that when participants forgot negative social feedback from their peers, their explicit attitudes became more positive toward the rejecters.

3.2 | ERP data

3.2.1 | Feedback-LPP

Positive social feedback evoked larger LPP amplitudes than negative social feedback (t(28) = 2.3, p = .031; positive vs. negative: 1.39 ± 3.00 μV vs. 0.55 ± 2.71 μV; Figure 3a). Moreover, a significant correlation was found between the LPP amplitude and the immediate recall accuracy for positive social feedback (r = 0.490, corrected p = .007; Figure 3b).

3.2.2 | Instruction-N2

The main effect of instruction was significant (F(1,28) = 6.2, p = .019, η_p^2 = 0.181; Figure 4a). The forget-instruction elicited larger N2 amplitudes (−2.90 ± 4.18 μV) than the remember-instruction (−1.71 ± 4.12 μV) regardless of the valence of social feedback. The main effect of valence (F(1,28) < 1, p = .867, η_p^2 = 0.001) and the valence by instruction interaction (F(1,28) < 1, p = .562, η_p^2 = 0.012) were not significant.

3.2.3 | Instruction-LPP

The main effect of instruction was significant (F(1,28) = 7.0, p = .013, η_p^2 = 0.200). The remember-instruction evoked larger amplitudes (1.59 ± 2.83 μV) than the forget-instruction (0.72 ± 3.28 μV). The valence by instruction interaction was significant (F(1,28) = 5.5, p = .026, η_p^2 = 0.165; Figure 4b). Decomposing the interaction suggests that TBR elicited larger LPPs than TBF only in the negative feedback condition (1.94 ± 2.79 μV vs. 0.52 ± 3.28 μV; F(1,28) = 12.0, p = .002, η_p^2 = 0.299). However, the LPP between TBR and TBF were not significantly different for positive social feedback (F(1,28) < 1, p = .427, η_p^2 = 0.023; TBR vs. TBF: 1.24 ± 2.86 μV vs. 0.92 ± 3.28 μV). No main effect of valence was found (F(1,28) < 1, p = .548, η_p^2 = 0.013).

4 | DISCUSSION

By combining the social judgment and directed forgetting paradigms, this study investigated voluntary memory control of social feedback and the associated neural correlates. We found that the valence of social feedback significantly influenced memory control and the associated ERPs. Additionally, memory control of social feedback could have a long-term

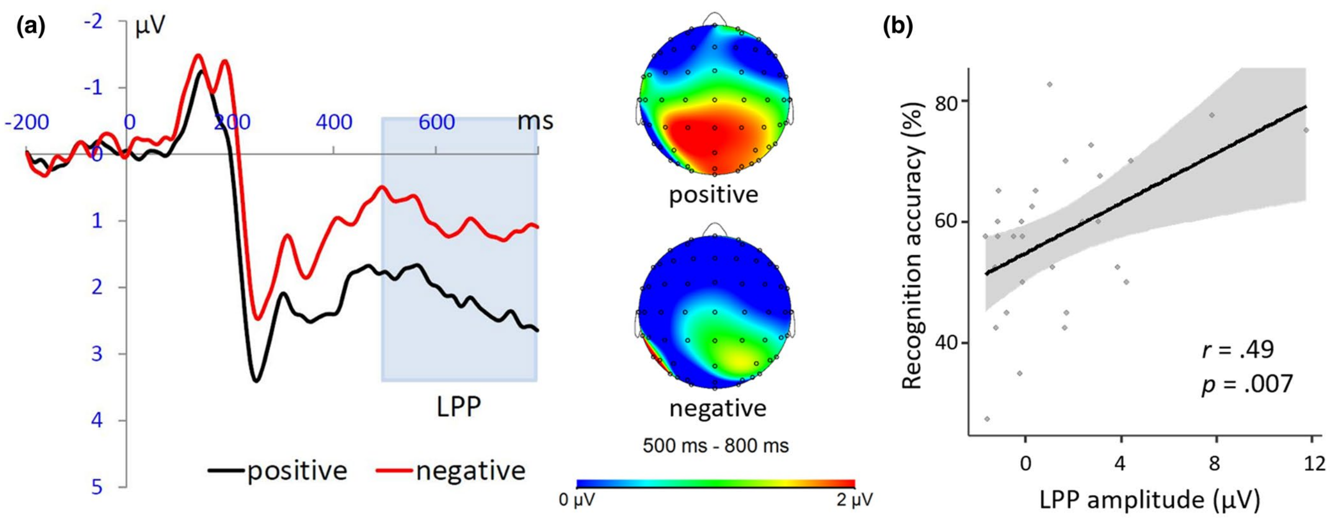

FIGURE 3 The grand-mean ERP waveforms evoked by social feedback and the correlation between behavioral and ERP indexes. (a) Parietal LPP. Waveforms were calculated by averaging the data at the electrodes of Pz, P3, and P4. Topographies were calculated by averaging the data within a time window of 500 to 800 ms after the onset of feedback. (b) Correlation between feedback-evoked LPP amplitude and the recognition accuracy of positive social feedback

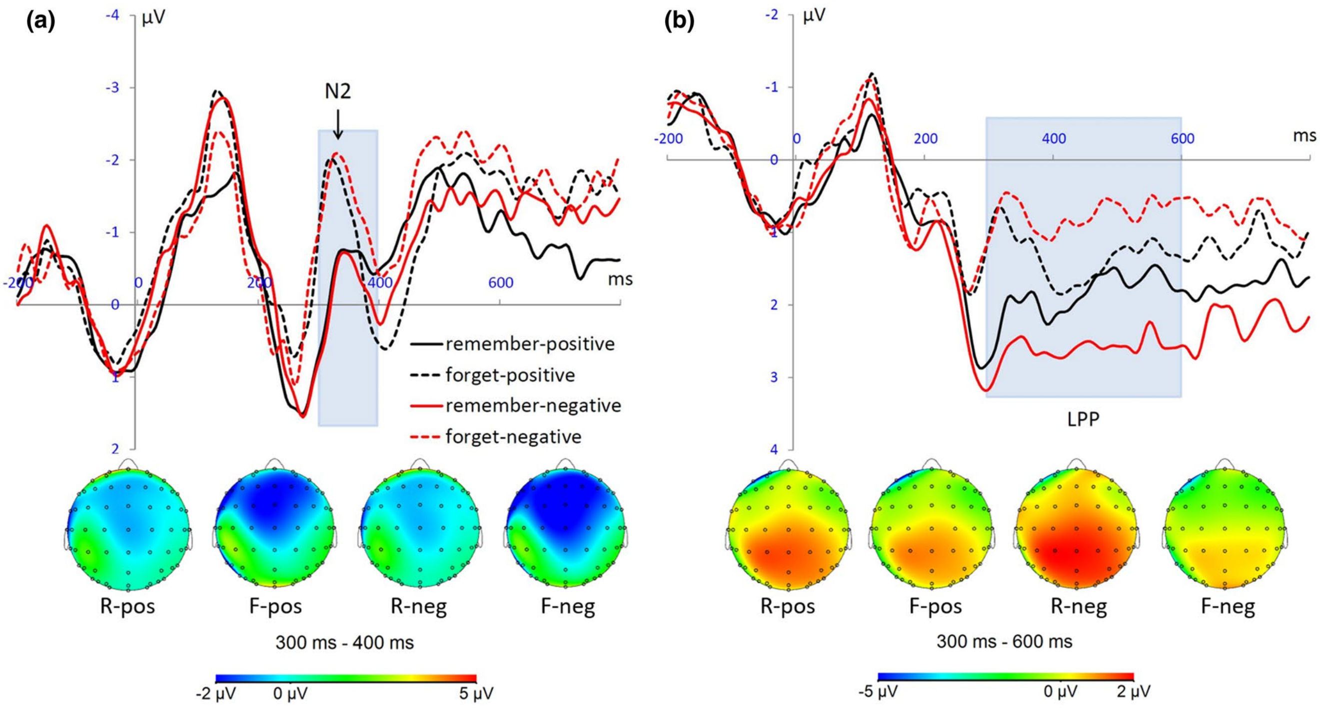

FIGURE 4 The grand-mean ERP waveforms evoked by instructive cues. (a) The N2 component. Waveforms were calculated by averaging the data at the electrodes of Fz, F1, and F2. Topographies were calculated by averaging the data within a time window of 300 to 400 ms after the onset of instructive cue. (b) The LPP. Waveforms were calculated by averaging the data at the electrodes of Pz, P3, and P4. Topographies were calculated by averaging the data within a time window of 300 to 600 ms after the onset of instructive cue

influence on people's explicit and implicit evaluations toward the feedback providers.

Recognition memory tests showed that people successfully forgot negative social feedback (i.e., social rejection) immediately after the DF task, which is consistent with prior literature demonstrating successful voluntary forgetting of negative nonsocial emotional materials (Barnier et al., 2007; Brandt et al., 2013; Tolin et al., 2002; Wessel & Merckelbach, 2006). Moreover, participants had larger DF effects for negative than for positive social feedback, providing behavioral evidence that forgetting unwanted negative feedback was easier than forgetting desirable, positive feedback. These results are consistent with the literature on motivated forgetting and self-evaluation, which revealed that in order to maintain self-esteem and a positive view about oneself, people are more likely to remember positive self-traits and are less likely to endorse negative self-traits, an effect termed as “mnemic neglect” (for a review, see Sedikides et al., 2016). The present study extended this result to external, social feedback: people are more efficient in voluntarily forgetting information conveying social rejection than social acceptance. At a neural level, our ERP results suggest that such a mnemic neglect effect originated at the encoding stage: negative social feedback elicited smaller LPP amplitudes than positive feedback, which is in line with previous literature on the processing of social emotional materials (Bublatzky et al., 2014; Funkhouser et al., 2020; Gu et al., 2020) and the insufficient integration theory proposed by Pinter et al. (2011). Moreover, during the memory control stage of negative feedback, we found that TBF items elicited larger cue-evoked N2 (i.e., cognitive control) while TBR items elicited larger cue-evoked LPP (i.e., in-depth encoding and elaboration). These ERP results are consistent with the typical ERP patterns associated with DF effect (Bailey & Chapman, 2012; Cheng et al., 2012; Gao et al., 2016; Hauswald et al., 2010; Hsieh et al., 2009; Patrick et al., 2015; Paz-Caballero et al., 2004; Schindler & Kissler, 2018; van Hooff & Ford, 2011; Xie et al., 2018; Yang et al., 2012). Based on these ERP findings, we tentatively propose that, people can voluntarily employ inhibitory control processes to limit the encoding of unwanted memories (in this study, negative social feedback), which then facilitated the forgetting of these unwanted memories (Anderson & Hanslmayr, 2014).

Unlike the findings for negative social feedback, participants showed no DF effect for positive social feedback, that is, people could not easily forget positive social feedback, even when instructed to do so. This result indicates that positive social feedback is more difficult to forget. This is consistent with some previous studies using nonsocial materials. For example, Payne and Corrigan (2007) reported that directed forgetting could not suppress the memory of emotionally positive pictures. Previous research has also found that positive autobiographical events were recalled better than negative events (Bahrick et al., 1996; Linton, 1986; Wagenaar, 1986), and that highly positive autobiographical events (such as a memorable holiday) were resistant to the influence of instructions to forget (Joslyn & Oakes, 2005). More recently, Pierguidi et al. (2016) demonstrated that neutral faces embedded in positive contexts were more difficult to forget than those embedded in neutral contexts. These authors argued that the encoding of positive TBF information was difficult to suppress because positive information (in comparison to negative information) broadens attentional focus, decreasing the efficiency of the inhibitory control system (Pierguidi et al., 2016). Whereas these prior studies proposed explanations for the cognitive mechanisms underlying DF of positive materials, the current finding supports the motivation theory in the context of social cognition. During the feedback encoding stage, the LPP was larger for positive social feedback than negative social feedback. Previous DF studies have considered the LPP to reflect motivated attention and elaborative processing of emotional contents (Bailey & Chapman, 2012; Hauswald et al., 2010; Xie et al., 2018; Yang et al., 2012). Thus, the current finding of feedback-LPP suggests that participants have a selective encoding bias to positive social feedback, supporting the claim that people have a positivity bias in processing self-relevant social information (Korn et al., 2012). During the DF stage, we observed comparable forget-cue-evoked N2 amplitudes for positive and negative social feedback, which is inconsistent with our predictions. This result indicates that memory control mechanism may not be affected by the previous encoding bias, and that participants can still allocate cognitive control resource to inhibit the processing of positive social information when instructed to do so, although they have intrinsic motivation to remember it. Taken together the ERP findings on the two stages, we propose that although participants made attempts to control TBF positive social feedback (reflected by the instruction-evoked N2), positive social feedback was relatively immune to the DF manipulation (when compared with negative social feedback) due to the selective encoding bias (reflected by the feedback-evoked LPP).

However, it should be noted that although the N2 component has widely been associated with inhibitory control of TBF items in the DF procedure (Anderson & Hanslmayr, 2014; Liu et al., 2020), there are also findings suggesting that the N2 reflects other cognitive processes rather than inhibition (e.g., conflict resolution or information discarding of TBF items; Schindler & Kissler, 2018). Furthermore, when considering the intrinsic tendency of mnemic neglect in healthy populations, we propose that it is possible the observed DF effect for negative social feedback mainly resulted from selective rehearsal of TBR items rather than the inhibitory control of TBF ones. Therefore, it is still urgent for further investigation on the neural mechanisms underlying voluntary forgetting of self-relevant social information, especially the long-debated role of inhibitory control in item-method DF. A promising direction is to study individuals with aberrant processing of social feedback (such as socially anxious and depressed individuals; for a review, see Rappaport & Barch, 2020) to differentiate between effects of encoding biases and deficits of control mechanisms.

Memory control not only reduces the accessibility of unwanted memories, but also has downstream effects on memories' unintended influences (Engen & Anderson, 2018; Hu et al., 2015, 2017; Vivas et al., 2016). Importantly, we found that voluntary forgetting of social rejection resulted in a more positive evaluation for the feedback senders. In particular, the results of the delayed AMP showed that the evaluation of positive judgment toward rejecters was higher for TBF than TBR negative social feedback. Interestingly, this effect only existed in the delayed test. This may be because implicit evaluation could not be changed over a short period (Gregg et al., 2006; Wyer, 2016), and the 3-day interval enabled consolidation and reinforcement of the memory control effect. Results on the explicit social evaluation task showed a similar picture: when people successfully forgot negative social feedback, their negative evaluations toward rejectors were reduced. These findings suggest that voluntary memory control of unwanted social feedback can affect people's spontaneous evaluations in the context of social interaction.

It is noteworthy that the DF effects on memory and emotional attitudes at different testing periods were dissociated. In the recognition memory test, a DF effect was found on memory of negative social feedback immediately after the DF task, but it disappeared after 3 days due to memory decay of the TBR information (Ebbinghaus, 1885; Rubin & Wenzel, 1996). In contrasts, changes in attitudes toward rejecters were observed only in the delayed test. This dissociation of time effects may be because memory and emotion are dependent on different brain systems which might work in distinct time spans (Adolphs, 2002; LeDoux, 1994; Phelps, 2004; Squire, 1986). Despite the different time effects, the current study's findings indicate that memory control of social feedback is beneficial in general because in the short term, it helps people forget unwanted negative social information, and in the long term, it helps decrease their emotional responses toward social rejecters. Future research could employ longer intervals to validate the current findings. It should be noted that the testing lag for the immediate test in this study actually fell in the time range of intermediate-term episodic memory, according to Kesner and Hunsaker (2010). However, we use “short-term” instead of “intermediate-term” throughout to intuitively separate the immediate test from the 3-day delayed test.

Some future work should be carried out to verify and extend the current findings. First, participants were instructed to remember or forget both faces and the associated social feedback during the SJ-DF task. Thus, the observed DF effect might be caused by memory control of social feedback or the face or both. We suggest future studies to examine memory control of these two items separately using additional tasks such as face recognition test. Second, it will be desirable for future research to add a neutral condition (e.g., neutral social feedback) in the SJ-DF task to serve as a neutral baseline. This would further constrain the explanations of the findings: whether positive feedback abolished the forgetting effects, or whether negative feedback enhanced people's memory control efficiencies. Third, the social feedback was provided by a panel of unfamiliar peers based on their first impression, which may only induce mild emotional experiences in participants. It has been revealed that arousal plays a role in voluntary forgetting of emotional materials (Zwissler et al., 2012), for example, highly arousal negative materials are exempt from voluntary forgetting (Hauswald et al., 2010). Therefore, we suggest including highly arousing social events (such as interpersonal conflict, divorce, and loss of relatives) in future work to extend the current findings and provide insights for the treatments of mental disorders characterized by deficient control of unwanted memory (Anderson & Hulbert, 2020; Nørby, 2018).

In conclusion, the current study investigated voluntary forgetting of social feedback and its influence on explicit/implicit attitudes toward the feedback providers. We found that voluntary forgetting of positive social feedback is more difficult than that of negative feedback due to people's preferential elaborative encoding before the presentation of DF instructive cues. Furthermore, forgetting negative social feedback can subsequently decrease people's explicit and implicit negative evaluations toward social rejecters, suggesting the potential benefits of forgetting in preserving self-esteem and in restoring social connection. These findings highlight the adaptive function of memory control (Engen & Anderson, 2018) and broaden the influence of voluntary forgetting in the context of social interactions. Future studies could examine whether impaired memory control of social information is a fundamental mechanism that underlies social anxiety and maladaptive attention/memory biases.

CONFLICTS OF INTEREST

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

AUTHOR CONTRIBUTIONS

Hui Xie: Formal analysis; Investigation; Writing-original draft; Writing-review & editing. **Xiaoqing Hu:** Conceptualization; Writing-review & editing. **Licheng Mo:** Data curation; Investigation. **Dandan Zhang:** Conceptualization; Funding acquisition; Methodology; Project administration; Supervision; Writing-review & editing.

DATA AVAILABILITY STATEMENT

The data and code of this study would be available upon reasonable request and with approvals of School of Psychology, Shenzhen University. More information on making this request can be obtained from the corresponding author, Prof. Dandan Zhang (zhangdd05@gmail.com).

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