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Inducing emotionally negative nonbelieved memories using negative pictures

Chunlin Li[1,2] · Henry Otgaar[1,2] · Peter Muris[2,3] · Yikang Zhang[2] · Jianqin Wang[4]

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Abstract
Memories that can be recalled but are no longer believed are termed nonbelieved memories. The current studies examined the creation of emotionally negative nonbelieved memories after viewing negatively valenced pictures. In both experiments, participants took part in two sessions. In Session 1, after being presented with a set of neutral and negative pictures, participants had to rate their emotional state. One week later, in Session 2, participants had to complete a recognition task to identify pictures that had appeared during the previous session. During this task, participants' memories for some pictures were challenged by telling them that their answers were incorrect in order to evoke nonbelieved memories. The experimental procedure was successful in creating nonbelieved memories in the participants. Specifically, in Experiment 1 ($N = 35$), we induced nonbelieved true memories for both negative and neutral pictures. We found a significant decrease in both belief and recollection after the challenge, with the change in belief being twice as large as the change in recollection. In Experiment 2 ($N = 43$), we successfully induced both nonbelieved true and false memories for negative pictures. Again, the reduction of belief was significantly greater than that of recollection. In general, participants evinced better memory for negative pictures, but following challenges people were just as likely to accept false social feedback and change their memories regarding other types of pictures. In both experiments, our challenges did not lead to notable changes in emotional state. In general, our findings show that emotionally negative nonbelieved memories can be successfully evoked in an experimental setting.

Keywords Nonbelieved memories · Negative pictures · Emotional state · Social feedback · Traumatic experience

Adam had a memory of driving in the countryside of Suffolk when he was young. Swerving around a corner—at the old oak tree road not far from home, he hit a milk float that was on the side of the road. The milk float fell over, and the road was covered with milk. He was in shock, felt guilty, and feared punishment for his stupid behavior. Later, he was told that this memory was not fully true: It was not him but his father who had been driving the car and caused this incident. He also had never lived in Suffolk. However, Adam could still vividly recall the road, the large oak tree, and the milk spilled all over the road (https://www.independent.co.uk/life-style/health-and-families/features/the-false-memory-archive-did-that-really-happen-9105226.html). In the case example here, Adam stopped believing that the negative event occurred even though he still had a lively recollection of it. Might this also happen in people with truly uncomfortable or negative memories (e.g., survivors of an earthquake or victims of sexual abuse; Horowitz, 1986; Scoboria et al., 2015a, b)? Or in other words, can people stop believing in the occurrence of highly negative events, and might this affect the emotional impact of these memories?

It is frequently argued that memory consists of the recollection of an event and the belief that it actually happened. For example, James (1890) proposed that "the mental side [of recall] is the conscious vision of the past occurrence, and the belief that we experienced it before" (p. 655). Autobiographical belief and recollection are two independent and continuous components of memory (Scoboria et al., 2014). Recollection includes the mental perception and

✉ Chunlin Li
Chunlin.li@kuleuven.be

1 Faculty of Law and Criminology, Catholic University of Leuven, 3000 Leuven, Belgium

2 Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands

3 Department of Psychology, Stellenbosch University, Stellenbosch, South Africa

4 Department of Psychology, Fudan University, Shanghai, China

reexperiencing of past experiences (Brewer, 1996; Rubin, 2005; Tulving, 1983), while belief refers to the truth value attributed to whether the event has actually occurred (Rubin, 2006). Scoboria and colleagues (2004) tested participants' memory using the Autobiographical Belief and Memory Questionnaire (ABMQ). The results showed that for most retrieved memories, belief and plausibility were both high. However, high plausibility did not necessarily imply high belief or recollection. As such, a nested model was proposed in which recollection and belief of a memory are considered as separate but related constructs. A canonical example of memories where belief and recollection can be considered as separate but related are so-called nonbelieved memories.

Nonbelieved memories

Memories (such as the abovementioned example of the Adam) that can be recalled but are no longer believed are termed nonbelieved memories (Mazzoni et al., 2010; Otgaar et al., 2014). Though discovered only recently, nonbelieved memories have been proven a quite common experience (Brédart & Bouffier, 2016; Mazzoni et al., 2010). In their survey study, Mazzoni and colleagues (2010) found that almost 25% of the 1,593 participants reported having experienced a nonbelieved memory. For example, one participant remembered seeing the real Santa Claus, one person remembered being a hockey player (even though she had never been engaged in this sport), and another participant could not find any reference to a film she remembered having seen.

In addition to naturally occurring nonbelieved memories, researchers have also successfully experimentally induced nonbelieved memories. Social feedback, that is, being told by others that one's memory is incorrect, is the main reason why people change their beliefs, and this is also the most effective way to elicit nonbelieved memories (e.g., Otgaar et al., 2013, 2017; Scoboria et al., 2015a, b; Wang et al., 2017). Clark and colleagues (2012) asked participants to copy actions performed by an experimenter such as clapping their hands and rubbing the table while their actions were video recorded. Two days later, participants were shown the recorded videos, but these had been edited and manipulated by the researchers. That is, the videos included footage of new actions that had not been performed during the previous session to let participants falsely "remember" and "believe" that they had also performed these fake actions (i.e., false memories). Finally, participants were told that the video clip had been manipulated; the fake actions were identified, and the belief and recollection of these actions were measured. This debriefing procedure reduced participants' belief in the fake actions by 10% to 30%, although they continued to have vivid recollections.

Otgaar and colleagues (2013) adapted a false-memory implantation procedure to experimentally elicit nonbelieved false memories in children and adults. In their study, the experimenter provided participants with information about a fictitious personal event (i.e., a balloon flight) and guided them to think about or imagine the details of that experience across multiple interviews. During each interview, participants also answered questions about the memory they had formed about the false event. Following the final interview, participants received a debriefing informing them that the event had never happened to them, after which they were asked questions about their belief and recollection of the event. It was found that about 38% ($n = 12$) of the participants indicated having a nonbelieved memory. That is, these participants reported reduced beliefs about the occurrence of the event after receiving the debriefing, but still had lively recollections of the event.

In another experiment, Otgaar and colleagues (2016) used an adaptation of Goff and Roediger's (1998) imagination inflation procedure to investigate nonbelieved true memories for actions in children and adults. Participants repeatedly performed, imagined, or heard statements about actions (e.g., *break a toothpick*) and then completed a memory test, some 2 weeks later, during which they made source judgments for all actions. For actions that the participant indicated as "performed," randomly selected items were challenged by social feedback, making the suggestion that the action had originally not been performed. In adults, belief was relinquished for 38.7% of the challenged items, while in child participants the relinquishment rate of the belief was 51.1%. In a follow-up study, Li and colleagues (2020) used a similar imagination inflation procedure to create nonbelieved memories for familiar and bizarre actions (e.g., "*balance the spoon on your nose*") and found that 73.8% ($n = 79$) of participants gave up their beliefs for the remembered actions following corrective feedback.

Importantly, many naturally occurring nonbelieved memories are concerned with negative experiences (Mazzoni et al., 2010; Otgaar et al., 2019). This raises the question as to what extent it is possible to experimentally induce nonbelieved memories for negative events. In a previous investigation, Wang and colleagues (2017) have examined the induction of nonbelieved memories of negative words, but obviously words (even those with a negative connotation) remain rather abstract and thus are a less adequate proxy of negative experiences. Therefore, in the current studies, we used pictures as stimulus material, as they are more concrete and emotionally arousing compared to words, and hence may elicit more vivid memories. The primary aim of this research was to examine whether nonbelieved memories can be experimentally induced for visually presented negative stimuli.

Negative memories

We often experience events in our lives that produce negative emotional reactions, and such events tend to reside firmly in our memories and significantly influence our psychological state and behavior (Brewin, 2015; Brewin et al., 2010; Magee et al., 2012). For example, one study found that individuals who experienced a lack of parental care, neglect, or abuse during childhood exhibited a higher frequency of negative emotional experiences and were more prone to adopting negative mindsets (Gilbert et al., 2011). Apparently, negative events are anchored in our memory system and can be remembered for a long time (Houle & Philippe, 2020).

People typically pay more attention to negative information than to positive information. Negative stimuli have been thought to elicit greater physiological, cognitive, and behavioral responses (Taylor, 1991) and have stronger and longer-lasting emotional effects than positive stimuli (Sheldon et al., 1996). Because cues to negative content are prioritized during retrieval, the likelihood increases that these experiences will be rehearsed (Christianson, 1992) or reactivated (Payne & Kensinger, 2018). When these memories return to mind, they are accessible and vivid, and people feel confident about their content, describing them in more detail (Williams et al., 2022).

When retrieval cues themselves are emotional (Kensinger & Corkin, 2003; Ochsner, 2000), individuals are more likely to report vivid, specific recollections of negative events from their past. However, there is a discrepancy between the subjective vividness of memory and its accuracy (Brewin & Langley, 2019). In fact, when retrieving the most negative events from our personal past, we tend to focus on those aspects that we perceive as the most central to the event, rather than on marginal details (Talarico et al., 2009), and people are barely aware of missing such details (Phelps & Sharot, 2008).

However, even negative memories are susceptible to modification (Talarico & Rubin, 2003). Based on the idea of memory reconsolidation, when a memory is reactivated, it has the potential to be modified, allowing new information to update old information through reactivation-induced updates, and the memory can again undergo another consolidation process (Elsey et al., 2018).

Studies of autobiographical memories have shown that belief in the occurrence of an event has a greater impact on behavioral change than recollection. For example, Bernstein and colleagues (2015) conducted a meta-analysis on eight food preference studies published between 2005 and 2008 and found that belief was more important than recollection in impacting people's attitudes and behavior. In a typical food preference experiment, participants were falsely told that they got sick after eating egg salad in their childhood to induce false beliefs of being sick of eating egg salad which led some participants to reduce the behavior of eating egg salad at a later moment (Wang et al., 2019a, b).

Hence, it is crucial to study how to reduce people's beliefs about negative memories, as it may be possible to alleviate the aftereffects associated with such memories. To our best knowledge, researchers have not yet explored whether social feedback can be used to change people's beliefs about negative memories. The lowering of belief about the occurrence of the negative events might also reduce people's negative emotions. The main purpose of the current research was to examine the effect of undermining beliefs of memories that are more distinctive and negatively valenced. Further, it was investigated whether undermining the belief in negative memories might lead to nonbelieved memories.

To achieve these goals, we conducted two experiments. In both experiments, participants took part in two sessions. In the first session, participants were exposed to negative and neutral (and positive; Experiment 2) pictures from the Open Affective Standardized Image Set (OASIS; Kurdi et al., 2017), and after the pictures were presented, participants had to rate their emotional state. One week later, in the second session, participants had to complete a recognition task to identify the pictures that had appeared in the first session. During this task, participants received feedback that challenged their memories of some of the pictures in order to reduce their belief that the pictures had appeared.

Our predictions were as follows. Based on earlier studies of nonbelieved memories (Li et al., 2020; Scoboria et al., 2015a, b), we anticipated that after receiving social feedback challenging their memories, participants' belief scores would decrease significantly, thereby creating nonbelieved memories of negative pictorial stimuli. Previous studies have shown that people's emotional states are influenced by their beliefs (Blanchette & Caparos, 2013; Frijda et al., 2000; Kneeland et al., 2016). Thus, we also predicted that when participants stopped believing that they had experienced a negative event, their emotional state would improve. As people might be more motivated to disbelieve negative memories (Page & Morrison, 2018; Romano et al., 2020; Ullman, 2007), we predicted that people would be more susceptible to the induction of nonbelieved memories for negative pictorial stimuli than for other stimuli.

Experiment 1

Method

Participants

In preceding studies in which a social feedback method was used to induce nonbelieved memories (Otgaar, et al., 2018; Wang et al., 2017, 2019a, b), Cohen's d for belief reduction (challenged vs. control conditions) fell between 0.50 and 1.42. Therefore, we opted for a conservative estimate of the effect size of Cohen's $d = 0.50$ in the current study. An a priori power analysis using G*Power (Faul et al., 2007) indicated that to detect a mean difference of Cohen's $d = 0.50$ between two dependent samples with $\alpha = .05$ and $1 - \beta = .80$ when using a two-tailed t test, a sample of 34 participants would be needed.

The participants were recruited from the Catholic University of Leuven, and this was done online, for example via the university-based online experimental sign-up system. Participants were excluded if they met any of the following criteria: a history of traumatic physical assault, sexual assault, road traffic accident, any past/current mental health problems requiring psychological and/or psychiatric treatment, blood-injection-injury phobia, and substance abuse. Forty people participated in the study. We excluded four participants who did not complete the second session and one with a history of traumatic physical assault. Thus, our final sample consisted of 35 participants, 19 males and 16 females, with ages ranging between 21 and 57 years ($M_{age} = 27.09$, $SD = 10.56$). After completion, five shopping vouchers (of 50 euros each) were raffled among the participants. The study was approved by the Social and Societal Ethics Committee (SMEC) and Privacy and Ethics (PRET) of the Catholic University of Leuven. Data are available online (https://osf.io/jdu45/).

Materials

Pictures We selected 100 pictures from the OASIS (Kurdi et al., 2017) which included 50 pictures depicting negative scenes (e.g., *death*) and 50 pictures depicting neutral scenes (e.g., *furniture*). We compared the valence (i.e., the positivity or negativity of the affective response) and arousal (i.e., the level of excitement that an observer experiences) of various pictures to determine their validity. A higher score indicated that the valence and arousal of that picture were rated as more positive/ higher. The arousal score of the negative pictures ($M = 4.69$, $SD = 0.35$) was significantly higher than that of the neutral pictures ($M = 2.07$, $SD = 0.19$), $t(98) = 46.37$, $p < .001$, Cohen's $d = 9.27$, 95% CI [2.51, 2.73], while the valence score ($M = 2.12$, $SD = 0.62$) was significantly lower than the neutral pictures ($M = 4.13$, $SD = 0.42$), $t(98) = -19.01$, $p < .001$, Cohen's $d = -3.80$, 95% CI [−2.22, −1.80]. Eighty target pictures including 40 negative pictures and 40 neutral ones were presented during encoding in random order during the first session of the experiment. The remaining 20 pictures (10 negative and 10 neutral) only appeared as "new" pictures (along with the 80 "old" pictures) in the recognition task which was administered during the second session.

Trauma History Screen (THS) The THS (Carlson et al., 2011) is a brief self-report scale for measuring the frequency of exposure to high-magnitude stressor (HMS) events (sudden events that cause extreme distress in most people exposed) and events associated with persisting posttraumatic distress (PPD) events. The scale has excellent temporal stability (HMS events: $r = .93$; PPD events: $r = .73$) and strong convergent validity as established via correlations with the PTSD Checklist (rs being 0.22 for university students and 0.41 for traumatized veterans; Carlson et al., 2011).

Beck Depression Inventory (BDI-II) The Beck Depression Inventory–II (BDI-II; Beck et al., 1996) is a 21-item measure for assessing the severity of depressive symptoms in the past 2 weeks. Items are rated on a 4-point Likert scale (e.g., 0 = *I do not feel I am worthless*, 3 = *I feel utterly worthless*; range: 0–63). The BDI-II shows very good internal consistency (with a Cronbach's alpha value of 0.93 among college students and 0.92 among outpatients; Beck et al., 1996) and correlates strongly with the depression subscale of the Symptom Checklist–90–Revised (SCL-90-R; $r = .89$; Steer al., 1997) and the Hamilton Psychiatric Rating Scale for Depression ($r = .71$; Beck et al., 1996), which supports the concurrent validity of the scale. In the current study, the Cronbach's α of the BDI-II was .85.

Positive and Negative Affect Schedule (PANAS) The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) consists of 10 items measuring positive affect and 10 items measuring negative affect. Items are rated on a scale ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). The measure has excellent temporal stability (negative affect: $r = .81$, positive affect: $r = .79$) and convergent and divergent validity (Watson et al., 1988). In the current study, Cronbach's αs before and after the exposure to the pictures were .90 and .92 for the positive affect and .93 and .93 for the negative affect scales, respectively.

Visual Analogue Scales (VASs) Visual analogue scales (VASs) were used to record subjective momentary mood states for anxiety, depression, happiness, and anger. These

mood states were selected in line with previous research (Baptie et al., 2021; Cuperus et al., 2017; Davis & Clark, 1998). Each mood was rated using an 11-point Likert scale (0 = *not at all anxious* to 10 = *extremely anxious*).

Memory Characteristic Questionnaire (MCQ) In the current study, an adapted version of the Memory Characteristics Questionnaire (MCQ; Johnson et al., 1988) was used. This questionnaire assessed the phenomenological aspects of the memories, such as visual details, auditory details, and associated feelings, all of which were rated on a 7-point Likert scale with 1 = *not at all* and 7 = *very much*. The current version of MCQ has already been employed in a previous study by Li et al. (2020).

Autobiographical Belief and Memory Questionnaire (ABMQ) The Autobiographical Belief and Memory Questionnaire (ABMQ; Scoboria et al., 2004) assesses general plausibility, personal plausibility, autobiographical belief, and recollection. Participants rated each item for each picture on an 8-point Likert scale. Two items of this measure were used in the current study. For the belief item, participants were asked "Do you believe that this picture has appeared before (regardless of whether you remember or not)?" (1 = *definitely did not happen*, 8 = d*efinitely did happen*). For the recollection item, participants were asked "Do you actually remember that this picture has appeared before?" (1 = *no memory of the picture at all*, 8 = *clear and complete memory*).

Design and procedure

Experiment 1 employed a 2 (pictures: old vs. new) × 2 (challenge: yes vs. no) within-subject design. Participants were tested individually during two online sessions which together lasted approximately 1.5 hours. All questionnaires were administered in Qualtrics, and the memory challenges were delivered via zoom meetings using a self-developed applet. We informed participants in the study advertisement and the information letter that participation would involve viewing some potentially disturbing pictures and that they could terminate the experiment at any time if they felt too uncomfortable. Further, in the unlikely event that a participant would experience adverse side effects, we provided him/her with the contact information of a (clinical) psychologist who if needed could provide professional counselling. Following informed consent procedures, participants completed the THS, BDI-II, and PANAS, respectively. To minimize hypothesis-guessing, we told participants that the study was to test people's memory. As noted earlier, the experiment consisted of two sessions.

In Session 1, the pictures were presented to participants on their computer screen in a randomized order. Participants were instructed to memorize as many pictures as they could. Each picture appeared for 2.5 s and was followed by a blank screen for 1.5 s. After all the pictures were presented, participants completed the PANAS again.

In Session 2, which took place one week after Session 1, participants completed a recognition task. The recognition task consisted of 80 pictures, 60 of which were "old" (previously presented) pictures and 20 of which were "new" (not previously seen) pictures. All the pictures were presented in a predetermined random order. Before the recognition task, the experimenter explained to the participants the differences between recollection and belief: "Recollection refers to the mental reexperiencing of an event. Belief, on the other hand, refers to the extent to which people believe the event really occurred in the way they remembered it." Participants were instructed to identify the picture on the screen as to whether it had appeared in the previous session by clicking on an "old" or "new" button. If a picture was remembered, participants would provide recollection and belief ratings on the ABMQ items (see supra), rated the phenomenological aspects of the memories for these pictures using the MCQ, and then rated their mood state by means of the VASs.

During the recognition task, memories for a number of correctly recollected appeared pictures were challenged. More precisely, every third picture that was correctly identified as "old" was disputed. After the participant had responded to the picture, a label beneath the picture popped up stating "*Sorry, your previous answer was incorrect. This picture did not appear before. Please think about the picture again*." Then immediately after the challenge, participants were asked to rate the recollection and belief for that picture, evaluated its phenomenological aspects, and rated their mood state using the VASs. A memory was labeled as a nonbelieved memory if the recollection score was 1 point higher than the belief score (Scoboria et al., 2018).

At the end of the second experimental session, participants were debriefed and thanked for their participation (Fig. 1).

Results

Recognition rates

In order to determine to what extent participants correctly identified the pictures, we obtained the true memory rate by dividing the number of correctly identified (old and new) pictures by the total number of pictures. In a similar way, the false memory rate was calculated by dividing the number of incorrectly identified (old and new) pictures by the total number of pictures. The true recognition rates were analyzed using a paired-sample *t* test, and the result showed that the true memory rate was higher for negative pictures (*M* =

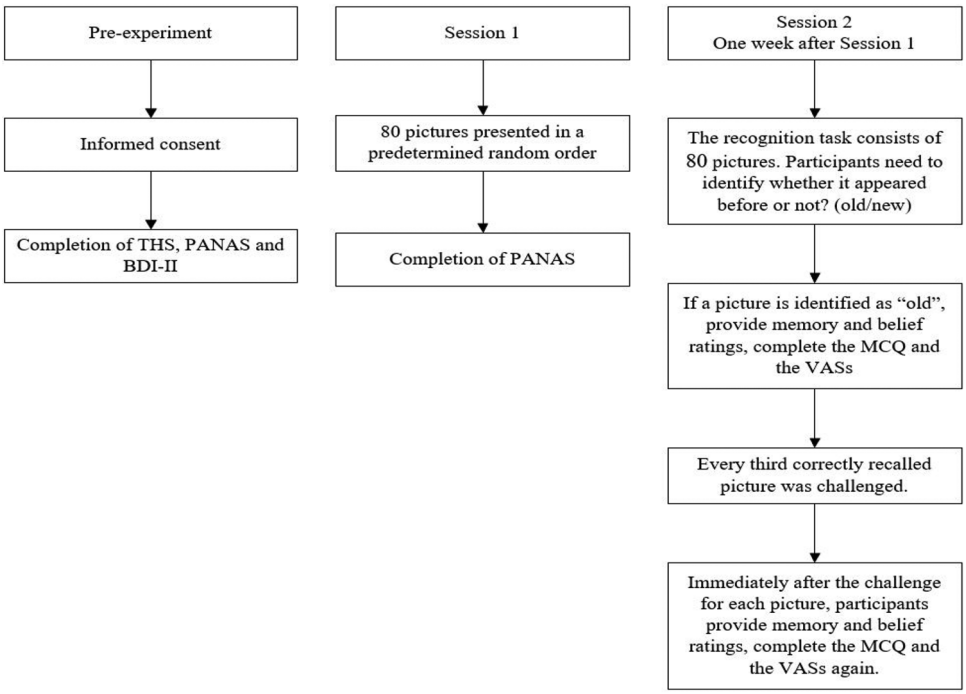

Fig. 1 Overview of the procedure of Experiment 1

0.62, $SD = 0.16$) than for neutral pictures ($M = 0.42$, $SD = 0.11$), t (34) = 9.67, $p < .001$, 95%CI [0.16, 0.24], Cohen's $d = 1.40$. Conversely, the false memory rate was higher for neutral pictures ($M = 0.58$, $SD = 0.11$) than for negative pictures ($M = 0.37$, $SD = 0.16$), $t(34) = -9.98$, $p < .001$, 95% CI [−0.25, −0.16], Cohen's $d = -1.44$ (see Fig. 2).

We also compared the hit rates of different categories of pictures. We defined the hit rate as the probability of

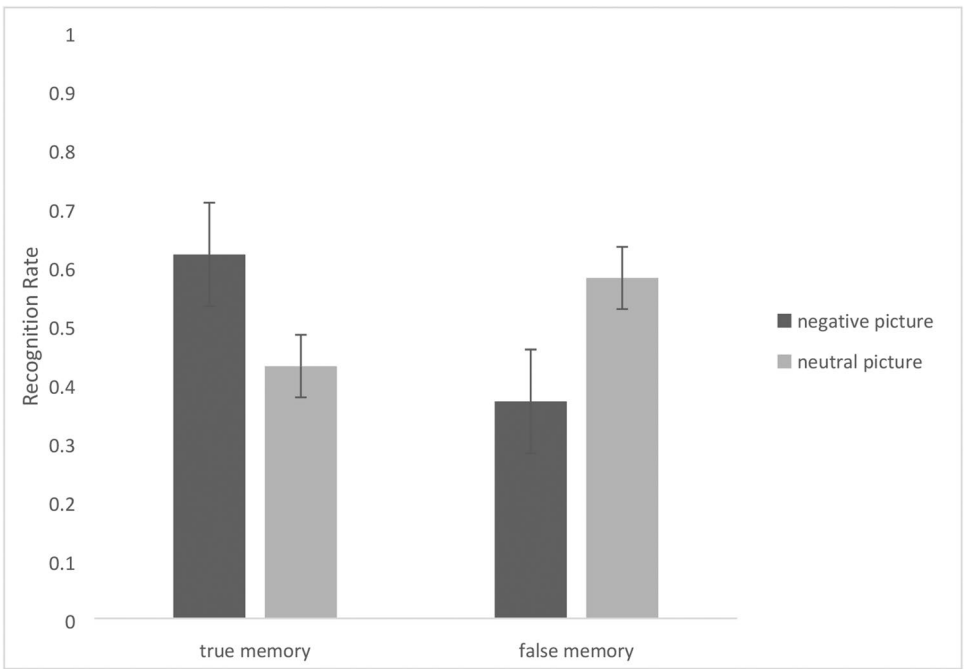

Fig. 2 Mean recognition rates of negative and neutral pictures in true and false memories. Error bars indicate 95% confidence interval

Table 1 Average number of challenges, NBMs, and nonbelieved memory rates for negative and neutral pictures (Experiment 1)

	Average number of challenges	Average number of NBMs	NBM rate
Negative pictures	4.89	1.86	38.03%
Neutral pictures	2.66	0.60	22.56%
All pictures	7.09	2.46	34.70%

correctly identifying the old pictures. The hit rate is obtained by dividing the number of hits by the total number of old pictures. A paired-sample *t* test was used to compare the difference in hit rates between negative and neutral pictures. It was found that the hit rates of negative pictures ($M = 0.78$, $SD = 0.30$) were significantly higher than those of neutral pictures ($M = 0.34$, $SD = 0.19$), $t(34) = 8.81$, $p < .001$, 95% CI [0.34, 0.54], Cohen's $d = 1.69$.

Nonbelieved memory rates

A memory was defined as a nonbelieved memory when the recollection rating for a picture was at least 1 point higher than the belief rating on an 8-point metric (Scoboria et al., 2004). Using this definition to the data collected before the challenge (as a baseline measurement), it was found that 12 participants displayed at least 1 one nonbelieved memory for negative pictures ($M_{number} = 0.60$, $SD = 1.04$), while there were 11 participants who had at least one nonbelieved memory for neutral pictures ($M_{number} = 0.40$, $SD = 0.70$). Table 1 shows the mean number of nonbelieved memories of neutral and negative pictures that participants had formed following the challenge. Overall, it was found that 68.57% ($n = 24$) of the participants had formed at least one nonbelieved memory. Participants had on average received 7.54 ($SD = 3.45$) challenges with regard to "old" pictures for which they formed on average 2.46 ($SD = 3.24$) nonbelieved memories. The nonbelieved memory rate (calculated by dividing the number of nonbelieved memories by the number of challenges received) was 34.70% for all pictures, and appeared to be higher for negative (38.03%) than for neutral pictures (22.56%), although this difference did not reach the conventional level of statistical significance, $t(28) = 2.01$, $p = .054$, 95% CI [−0.001, 0.15], Cohen's $d = 0.20$. When we used Wilcoxon signed-ranks test to compare the number of nonbelieved memories produced by the participants before and after the challenge indicated that the number of nonbelieved memories generated after challenge was significantly higher than before, $Z = 2.44$, $df = 34$, $p = .015$, $\varphi_c = 0.67$. This effect was carried by the increase of nonbelieved memories of negative pictures, $Z = 2.84$, $df = 34$, $p = .005$, $\varphi_c = 0.60$; for the neutral pictures, no significant difference in the number of nonbelieved memories produced before and after the challenge was noted, $Z = 0.91$, $df = 34$, $p = .361$, $\varphi_c = 0.62$.

Changes in recollection and belief following challenging feedback

We used a 2 (picture type: negative vs. neutral) × 2 (Memory component: belief vs. recollection) × 2 (time: before vs. after) repeated-measures ANOVA to analyze the memory ratings for both picture types before and after the challenging feedback (see Table 2). Results showed that there was a statistically significant interaction effect of memory component and time, $F(1, 30) = 7.51$, $p = .010$, partial $\eta^2 = .20$. There was also a statistically significant interaction effect of memory component and picture type, $F(1, 30) = 4.98$, $p = .033$, partial $\eta^2 = .14$. Further, main effects of time, $F(1, 30) = 27.47$, $p < .001$, partial $\eta^2 = .48$, and picture type, $F(1, 30) = 12.62$, $p = .001$, partial $\eta^2 = .30$, were noted, but there was no main effect of memory component, $F(1, 30) = 2.18$, $p = .151$, partial $\eta^2 = .07$. No statistically significant interaction effect of picture type and time, $F(1, 30) = .12$, $p = .731$, partial $\eta^2 = .004$, was found, and there was neither a statistically significant interaction effect between picture type, memory component, and time, $F(1, 30) = 2.65$, $p = .114$, partial $\eta^2 = .08$.

The two-factor interaction effect of memory component and time was significant, $F(1, 34) = 11.36$, $p = .002$, partial $\eta^2 = .25$. The results showed that the main effect of Time was significant, $F(1, 34) = 33.02$, $p < .001$, partial $\eta^2 = .49$. However, for memory component it was not significant, $F(1, 34) = 3.29$, $p = .079$, partial $\eta^2 = .09$. There were significant decreases in belief, $t(34) = 5.39$, $p < .001$, 95% CI [0.79, 1.74], Cohen's $d = 0.97$, and recollection scores, $t(34) = 3.81$, $p = .001$, 95% CI [0.24, 0.78], Cohen's $d = 0.44$,

Table 2 Recollection and belief scores before and after the provision of challenging feedback

Memory component	Before		After		Change (Before-After)	Cohen's *d*
	M	*SD*	*M*	*SD*		
Belief	5.98	0.99	4.71	1.50	1.18***	0.97
Recollection	5.86	1.08	5.35	1.20	0.52**	0.44

**$p < .01$; ***$p < .001$

following the challenge. The reduction of belief ($M = 1.18$, $SD = 1.38$) was significantly greater than the reduction of recollection ($M = 0.52$, $SD = 0.78$), $t(34) = 2.74$, $p = .010$, 95% CI [0.17, 1.15], Cohen's $d = 0.53$. Simple effect analyses showed that before the challenge, the difference between beliefs ($M = 5.98$, $SD = 0.99$) and recollections was not significant ($M = 5.86$, $SD = 1.08$), $t(34) = 1.50$, $p = .142$, 95% CI [0.04, 0.29], Cohen's $d = 0.12$. After the challenge, the scores of belief ($M = 4.71$, $SD = 1.50$) were significantly lower than recollection showed significant differences ($M = 5.35$, $SD = 1.20$), $t(34) = 2.63$, $p = .013$, 95% CI [0.14, 1.13], Cohen's $d = 0.47$.

In the interaction effect of memory component and picture type also found statistically significant, $F(1, 34) = 4.97$, $p = .033$, partial $\eta^2 = .14$. The main effect of Picture type was statistically significant, $F(1, 34) = 12.62$, $p = .001$, partial $\eta^2 = .30$, while the main effect of memory component was not statistically significant, $F(1, 34) = 2.18$, $p = .149$, partial $\eta^2 = .07$. Simple effect analyses showed that for negative pictures, belief scores ($M = 5.56$, $SD = 1.04$) were significantly lower than recollection scores ($M = 5.88$, $SD = 1.09$), $t(34) = 2.26$, $p = .030$, 95% CI [0.03, 0.61], Cohen's $d = 0.30$. For neutral pictures, the difference between belief ($M = 5.11$, $SD = 1.35$) and recollection scores was not significant ($M = 5.21$, $SD = 1.28$), $t(30) = 0.67$, $p = .506$, 95% CI [−0.43, 0.22], Cohen's $d = 0.08$.

Emotional change after challenging feedback

We conducted a paired-sample t test on the VASs scores to evaluate the changes in the emotional state of the participants following the challenge. The results did show that in general the VASs scores for negative pictures ($M = 3.01$, $SD = 1.54$) were significantly higher than those for neutral pictures ($M = 1.67$, $SD = 0.96$), $t(29) = 5.22$, $p < .001$, 95% CI [0.82, 1.87], Cohen's $d = 1.00$. The VAS scores before the challenge ($M = 2.18$, $SD = 1.23$) were significantly smaller than those after the challenge ($M = 2.45$, $SD = 1.31$), $t(34) = 3.37$, $p = .002$, 95% CI [0.11, 0.43], Cohen's $d = 0.21$. However, the VAS scores before and after the challenge did not show significant differences for either neutral or negative pictures (see Supplementary Materials for specific data, available at link: https://osf.io/jdu45/).

We conducted an exploratory correlation analysis to examine whether the phenomenological qualities of the memory (as measured with the MCQ) would impact the number of nonbelieved memories. There was no statistically significant correlation between MCQ scores and the number of nonbelieved memories, $r(35)$s ranged from −0.05 to 0.31, all ps $> .05$.

To summarize, in Experiment 1, we successfully induced nonbelieved memories for negative and neutral pictures. Twenty-four out of 35 (68.57%) participants formed at least one nonbelieved memory. When facing challenges, people were as likely to accept false social feedback regarding negative pictures and change their memories as for other pictures. The nonbelieved memory rate for negative pictures was as high as that of neutral ones. However, there was a significant increase in the number of nonbelieved memories for negative pictures before and after the challenge, whereas no such difference was observed for neutral pictures. Recollection and belief scores after challenging feedback both dropped significantly, but the decline in belief scores showed a more substantial decrease than the decline in recollection scores, which is line with earlier research (Li et al., 2020; Otgaar et al., 2013; Scoboria et al., 2018; Wang et al., 2017). Furthermore, negative pictures were associated with a higher recognition rate than neutral pictures, which means people had a better memory of the negative pictorial stimuli.

We used the mean VAS scores for all challenged pictures of each participant to evaluate the changes in the emotional state of the participants before and after the challenge. VAS scores increased significantly after the challenge compared to before the challenge. This means that the mood states of the participants became more negative after the challenge. This may be due to the fact that they needed to remember whether they had seen those negative pictures again after the challenge. The repeated recall of negative pictures probably caused discomfort and made participants feel worse.

In Experiment 1, only participants' true memories were challenged, so we could not compare the difference in the occurrence of nonbelieved memories generated by true and false memories. To address this issue, Experiment 2 was conducted. We largely relied on the methodology of Experiment 1, but during the recognition test of Experiment 2, feedback was given about correctly or incorrectly identified "old" pictures, thereby challenging both true memories and false memories. Furthermore, to further investigate the effects of challenging feedback on people's memories for different stimulus materials, we added a positive picture type in addition to the negative and neutral pictures used in Experiment 1.

Experiment 2

Method

Participants

An a priori power analysis using G*Power (Faul et al., 2007; the difference between two dependent means, paired-samples (two-tailed) t test, $d = .5$, $\alpha = .05$, $1 - \beta = .80$) indicated that at least 34 participants would be needed. Fifty-five people participated in Experiment 2. However, seven participants did not complete the second session, two did not

fully understand the experimental procedure, and three other participants reported a history of physical assault trauma. These 12 participants were excluded from the analyses, leaving a final sample of 43 (29 females and 14 males; M_{age} = 21.19, SD_{age}= 2.62). Participants received a 5-euro voucher for their participation. The experiment was approved by the Social and Societal Ethics Committee (SMEC) and Privacy and Ethics (PRET), the Catholic University of Leuven. Data of Experiment 2 are available online (https://osf.io/jdu45/).

Materials, design, and procedure

The materials, design, and procedure were largely the same as in Experiment 1. We selected 180 pictures from the OASIS (Kurdi et al., 2017), which included 60 pictures depicting negative scenes (e.g., *death*), 60 pictures depicting positive scenes (e.g., *fireworks*), and 60 pictures depicting neutral scenes (e.g., *furniture*). The arousal score was highest for the negative pictures (M = 4.65, SD = 1.94), followed by the positive pictures (M = 4.61, SD = 1.65), and finally the neutral pictures (M = 2.09, SD = 1.38), $F(2, 177) = 1252.07$, $p < .001$, Cohen's $d = 2.19$. For valence, positive pictures ($M = 5.57$, $SD = 1.14$) were associated with the highest scores, followed by the neutral pictures ($M = 4.15$, $SD = 0.76$), and the negative pictures (M = 2.33, SD = 1.09), $F(2, 177) = 395.12$, $p < .001$, Cohen's $d = 2.45$.

In the first session we presented participants with 120 pictures—40 neutral, 40 positive, and 40 negative pictures—in a random order. The recognition task, which was conducted one week later, also included 120 pictures, but this time half of the pictures (20 neutral, 20 positive, and 20 negative pictures) were "old" (already shown during the first session), while the other half (20 neutral, 20 positive and 20 negative pictures) was "new" (not shown before). During the test, every third picture with an "old" response of each category was challenged, regardless of if it was correctly or incorrectly identified. When a certain target picture appeared on the screen, a label beneath the picture popped up stating "*Sorry, your previous answer was incorrect. This picture did not appear before. Please think about the picture again.*" Immediately after the challenge of a picture, participants provided recollection and belief scores for that picture, rated the characteristics of the memory of that picture using the MCQ, and rate their mood state using the VASs (Fig. 3).

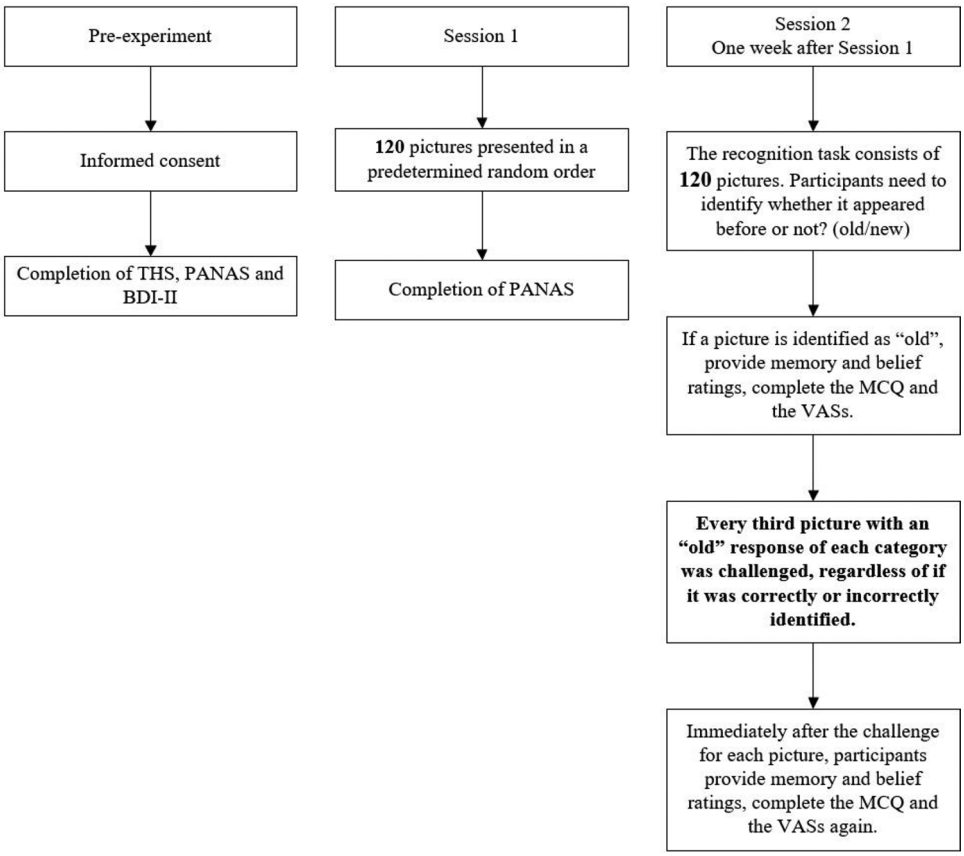

Fig. 3 Overview of the procedure of the Experiment 2

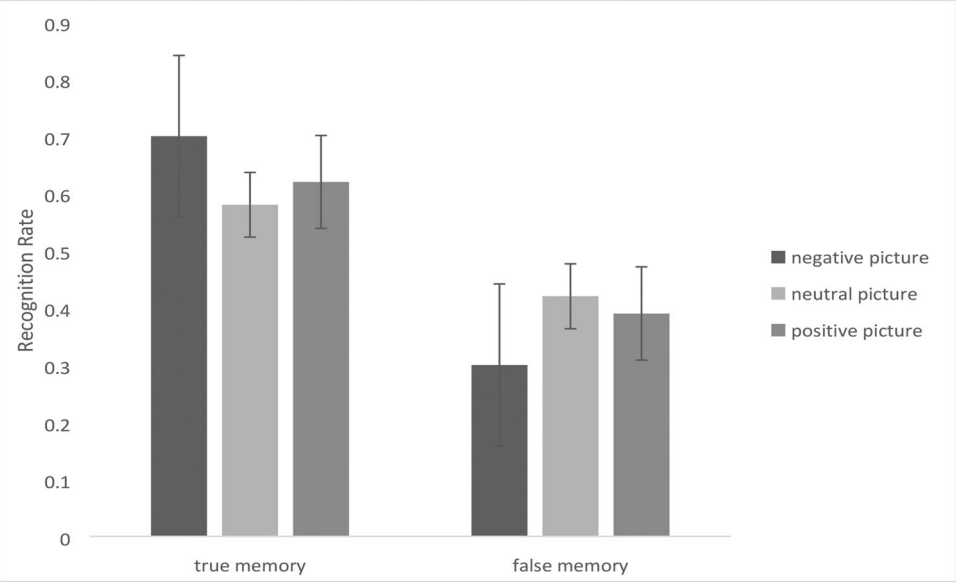

Fig. 4 Mean recognition rates of negative, neutral, and positive pictures for true and false memories. Error bars indicate 95% confidence interval

Results

Recognition rates

The true recognition rates were analyzed using a repeated measures ANOVA. The results revealed a statistically significant main effect, $F(2, 84) = 44.26$, $p < .001$, partial $\eta^2 = .51$. Negative pictures ($M = 0.70$, $SD = 0.09$) were associated with higher recognition rates than positive pictures ($M = 0.62$, $SD = 0.07$), $t(42) = 6.19$, $p < .001$, 95% CI [0.06, 0.11], Cohen's $d = 1.05$, which in turn were associated with higher recognition rates than neutral pictures ($M = 0.58$, $SD = 0.09$), $t(42) = 2.83$, $p = .007$, 95% CI [0.01, 0.06], Cohen's $d = 0.45$ (Fig. 4).

Again, we examined the difference in hit rates for each of the three picture types and the results showed that negative pictures ($M = 0.53$, $SD = 0.17$) were associated with significantly higher hit rates than positive ($M = 0.33$, $SD = 0.18$), $t(42) = 7.99$, $p < .001$, 95% CI [0.14, 0.25], Cohen's $d = 1.14$, and neutral pictures ($M = 0.29$, $SD = 0.21$), $t(42) = -10.57$, $p < .001$, 95% CI [0.19, 0.28], Cohen's $d = 1.21$. The mean hit rate of positive pictures ($M = 0.33$, $SD = 0.18$) was not significantly higher than that of neutral pictures ($M = 0.29$, $SD = 0.21$), t (42) = 1.60, $p = .118$, 95% CI [0.01, 0.09], Cohen's $d = 0.13$.

Nonbelieved memory rates

Similar to Experiment 1, a nonbelieved memory was defined when the memory rating was at least 1 point higher than the belief rating on an 8-point metric (Scoboria et al., 2004). Before the challenge, there were 26 participants with at least one nonbelieved memory ($M_{\text{number}} = 1.33$, $SD = 1.55$). Each participant produced on average 1.05 nonbelieved true memories ($SD = 1.38$)—that is, 0.42 ($SD = 0.63$) for negative pictures, 0.40 ($SD = 0.70$) for neutral pictures, and 0.23 ($SD = 0.61$) for positive pictures), and 0.30 nonbelieved false memories ($SD = 0.60$; i.e., 0.16 ($SD = 0.43$) for negative pictures, 0.07 ($SD = 0.26$) for neutral pictures, and 0.07 ($SD = 0.26$) for positive pictures.

Table 3 shows the mean number of nonbelieved memories that participants had formed after the challenge, the mean number of challenges they had received, and the nonbelieved memory rate for true and false memories in relation to various picture types. Overall, 90.70% ($n = 39$) of the participants had formed at least one nonbelieved memory. On average participants had received 6.77 challenges in response to "old" pictures, after which they formed 2.56 nonbelieved true memories (resulting in a nonbelieved true memory rate of 37.81%). For "new" pictures they had received on average 2.05 challenges for which they formed 0.91 nonbelieved false memories (resulting in a nonbelieved false memory rate of 44.39%).

We used a 2 (memory type: true vs. false) × 3 (picture type: negative vs. neutral vs. positive) repeated-measures ANOVA to analyze the nonbelieved memory rates. No significant main effects of memory type, $F(1, 5) = 1.96$, $p = .220$, partial $\eta^2 = .28$, and picture type, $F(2, 10) = 0.26$, $p = .777$, partial $\eta^2 = .049$, were found, and there was neither a statistically significant interaction effect, $F(2, 10) = 1.81$, $p = .214$, partial $\eta^2 = .27$.

Table 3 The percentages of nonbelieved true and false memory rates for negative, neutral, and positive pictures

	True memories			False memories		
	NBMs	Number of challenges	NBM rate	NBMs	Number of Challenges	NBM rate
Negative Pictures	1.30	3.09	42.07%	0.40	0.81	49.38%
Neutral Pictures	0.63	1.79	35.20%	0.26	0.60	43.33%
Positive Pictures	0.63	1.88	33.51%	0.26	0.63	41.27%
All pictures	2.56	6.77	37.81%	0.91	2.05	44.39%

A comparison of the number of nonbelieved memories produced by participants before and after the challenge showed that the number of nonbelieved memories increased following the challenging feedback, $Z = 5.17$, $df = 42$, $p < .001$, $\varphi_c = 0.71$. This was the case for true nonbelieved memories (negative pictures: $Z = 4.67$, $df = 42$, $p < .001$, $\varphi_c = 0.75$, neutral pictures: $Z = 2.67$, $df = 42$, $p = .008$, $\phi_c = 0.45$, and positive pictures: $Z = 3.13$, $df = 42$, $p = .002$, $\varphi_c = 0.50$) and false nonbelieved memories (negative pictures: $Z = 2.50$, $df = 42$, $p = .013$, $\varphi_c = 0.59$, neutral pictures: $Z = 2.31$, $df = 42$, $p = .021$, $\varphi_c = 0.31$, and positive pictures: $Z = 2.83$, $df = 42$, $p = .005$, $\varphi_c = 0.67$).

Recollection and belief after challenged feedback

We conducted a 3 (picture type: negative vs. neutral vs. positive) × 2 (memory component: belief vs. recollection) × 2 (time: before vs. after) repeated-measures ANOVA to analyze the belief and memory recollection ratings for various picture types as provided by the participants before and after challenge (see Table 4). No statistically significant interaction effect of picture type, memory component, and time, $F(2, 68) = .99$, $p = .375$, partial $\eta^2 = .03$, was noted. However, we did find significant interaction effects between picture type and memory component, $F(1, 34) = 4.04$, $p = .022$, partial $\eta^2 = .11$, and between memory component and time, $F(1, 34) = 18.46$, $p < .001$, partial $\eta^2 = .35$, and there were also significant main effects of time, $F(1, 34) = 47.54$, $p < .001$, partial $\eta^2 = .58$ and picture type, $F(1, 34) = 3.56$, $p = .034$, partial $\eta^2 = 0.10$. No significant main effect of memory was found, $F(1, 34) = 0.15$, $p = .701$, partial $\eta^2 = .004$. Simple effect analyses showed that for negative pictures, significant changes of belief, $t(42) = 6.75$, $p < .001$, 95% CI [1.46, 2.71], Cohen's $d = 1.17$, and recollection, $t(42) = 5.48$, $p < .001$, 95% CI [0.80, 1.74], Cohen's $d = 0.81$, were found as a result of the challenging feedback. The reduction of belief ($M = 2.08$, $SD = 2.02$) was significantly larger than that of recollection ($M = 1.27$, $SD = 1.52$), $t(42) = 5.07$, $p < .001$, 95% CI [0.49, 1.13], Cohen's $d = 0.40$. Significant changes of belief and recollection ratings from before to after the challenge were also noted for neutral pictures, $t(35) = 5.72$, $p < .001$, 95% CI [0.85, 1.79], Cohen's $d = 0.81$, and $t(35) = 4.69$, $p < .001$, 95% CI [0.47, 1.18], Cohen's $d = 0.52$, respectively, with the reduction of belief ($M = 1.32$, $SD = 1.38$) being significantly larger than that of recollection ($M = 0.82$, $SD = 1.05$), $t(35) = 2.14$, $p = .039$, 95% CI [0.03, 0.96], Cohen's $d = 0.40$. For positive pictures, a comparable pattern of findings was noted, belief and recollection ratings decreased following the challenge, $t(39) = 5.83$, $p < .001$, 95% CI [0.95, 1.96], Cohen's $d = 0.86$, and $t(39) = 4.60$, $p < .001$, 95% CI [0.57, 1.47], Cohen's $d = 0.63$, respectively. Again, the reduction of belief ($M = 1.45$, $SD = 1.58$) was significantly larger than that of recollection ($M = 1.02$, $SD = 1.40$), $t(39) = 2.75$, $p = .009$, 95% CI [0.11, 0.75], Cohen's $d = 0.29$.

Table 4 Recollection and belief scores for negative, neutral, and positive pictures before and after the provision of challenging feedback

		Before		After		Change (Before-After)	Cohen's *d*
		M	*SD*	*M*	*SD*		
Belief	Negative pictures	6.27	1.30	4.19	2.09	2.08***	1.17
	Neutral pictures	5.31	1.43	3.99	1.74	1.32***	0.81
	Positive pictures	5.91	1.45	4.46	1.84	1.45***	0.86
Recollection	Negative pictures	6.05	1.33	4.78	1.73	1.27***	0.81
	Neutral pictures	5.18	1.48	4.40	1.66	0.82***	0.52
	Positive pictures	5.45	1.63	4.43	1.61	1.02***	0.63

***$p < .001$

Emotional change after challenged feedback

We used the scores on the VASs to evaluate the change in the emotional state of the participants as a result of the experimental challenge. A paired-samples *t* test revealed that there was no statistically significant change in VASs scores following the challenging feedback (before: $M = 2.08$, $SD = 1.19$; after: $M = 2.20$, $SD = 1.42$), $t(42) = -0.94$, $p = .351$, 95% CI [−0.38, 0.14], Cohen's $d = -0.09$. When we compared the VAS scores for each of the three picture types (irrespective of time point), we found that the differences between negative pictures on the one hand and neutral pictures ($p = .015$, with a difference of 1.45, 95% CI [0.28, 2.61]) and positive pictures ($p = .028$, with a difference of 1.28, 95% CI [0.14, 2.41]) were statistically significant. The difference between the positive pictures and the neutral pictures was not statistically significant ($p = .774$, with a difference of 0.17, 95% CI [−1.01, 1.35]) (see Supplementary Materials for more details which are available at: https://osf.io/jdu45/).

We also conducted an exploratory correlation analysis to examine whether phenomenological features of the memories (MCQ) would be associated with the number of nonbelieved memories. There was no statistically significant correlation between MCQ scores and the number of nonbelieved memories, $r(43)$s ranged from −0.23 to 0.02, all ps $> .05$.

General discussion

We conducted two experiments to examine whether nonbelieved memories for negative pictures could be created. The current experiments are among the first to successfully induce nonbelieved memories for negative experiences in an experimental setup. Two main findings were observed. First, we successfully induced nonbelieved memories of negative experiences using negative pictures as stimuli. Specifically, participants showed significant decreases in both belief and recollection scores after their memories had been challenged, with the belief scores showing the most substantial decrease. Second, although people had a better memory of negative pictures compared with neutral and positive pictures, they were equally susceptible to accept challenging social feedback to all types of pictures and to form nonbelieved memories for these stimuli (i.e., neutral pictures in Experiment 1, neutral and positive pictures in Experiment 2).

In both studies, negative pictures were associated with a higher recognition rate for true memories than the other types of pictures and a lower recognition rate for false memories, which means that people have a better memory for negative pictures than for neutral and positive pictures. This is consistent with previous studies showing that negative memories are better retained in memory, contain more details of events (Kensinger & Schacter, 2006) and have more instructive functions (e.g., avoidance of injuries that were received previously) compared to positive memories (Rasmussen & Berntsen, 2009).

It is worth noting that even at baseline, without any challenge, participants demonstrated a certain degree of nonbelieved memories. This indicates that such memories are not exclusively the product of the challenge process but may also occur naturally. This could be interpreted as an indication of participants' confidence in their own memory, with lower belief scores perhaps suggesting less confidence. For instance, it might be indicative of an individual's general tendency to question one's memory based on the pictures presented. However, it could also reflect other cognitive or emotional processes, such as self-doubt or a response to avoid recalling negative experiences. Further research is required to investigate these possibilities and their implications for our understanding of memory and belief.

One of our main findings concerned our success in creating nonbelieved memories for negative pictures. The main reason why such nonbelieved memories were created was because participants received false feedback and thus were challenged on their memories for the pictures. Also, for the participants in our experiments, the experimenter seemed to be more of an authoritative presence, and hence the provided false feedback seemed to be reliable thereby making the participants reduce belief in their memories.

Interestingly, people were equally likely to accept false social feedback for different types of pictures. Indeed, the nonbelieved memory rates of negative pictures were as high as that of neutral ones. However, when we looked at the effect size of belief reduction, the Cohen's *d* of negative pictures was larger than that of neutral or positive pictures. This means that although negative memories were oftentimes well remembered, people still seemed to be willing to accept that such memories were not true. This is an important finding as there is evidence showing that it is belief and not recollection that serves as the primary driver of people's memory-based behaviors (Wang et al., 2017, 2019a, b). Our finding that nonbelieved memory rates were equally high for different types of pictures aligns with findings from Scoboria and colleagues (2014). They found that 4.3% of respondents cited personal motivation of feeling uncomfortable or disliking the content of their memory as factors leading to reduce belief. They successfully forced themselves to withdraw their beliefs from their memory, thus forming nonbelieved memories.

In addition to being not willing to recall painful experiences, we can also consider another mechanism for the finding that we succeeded in eliciting nonbelieved memory rates for negative pictures, namely persuasion. Petty and Cacioppo (1981) proposed the elaboration likelihood model

of persuasion and argued that the course of persuasion is based on how much mental processing or elaboration the target undergoes. According to an individual's motivation and ability to process information, this elaboration likelihood model includes a peripheral route to persuasion and a central route. The peripheral route is used whenever the target's motivation or ability to think about the problem is low. Recipients tend to focus on source characteristics or potential rewards for adhering to a message, rather than message content. Any resulting persuasion is not the result of active consideration of the issue, but rather the result of peripheral "persuasion cues" (e.g., being told that the picture had not appeared). When false social feedback (i.e., persuasion cues) was presented that the negative pictures that the participants wanted to avoid were not presented before. Participants who were reluctant to recall the negative pictures would use the peripheral route, focusing more on the potential rewards of social feedback, accepting that feedback, and changing their memories. Negative memories and memories of mundane experiences also differ in terms of the quality of memory. Negative memories contain more memory details and may retrigger those similar painful feelings, such as frustrating disappointment (Bower, 1981). Withdrawing beliefs about these memories seems to be a better option for people.

In this study, we focused on the production of nonbelieved memories for true events in Experiment 1 and expanded our investigation to include both true and false events in Experiment 2. Despite challenging true memories exclusively in Experiment 1, we found a higher rate of nonbelieved memories for false events in Experiment 2. For true memories, although they were challenged more frequently, it seems to be more difficult for participants to disbelieve these memories, possibly due to the stronger cognitive representation of the true events. Conversely, for false memories, even though they were challenged less often, the nonbelieved memory rate was higher. This could be because the cognitive representation of the false event is inherently weaker, making the memory more susceptible to disbelief when challenged. Our findings indicate that factors such as the frequency of challenges and the inherent nature of the memory itself can significantly impact the production of nonbelieved memories. Future research could examine these distinctions to further our understanding of nonbelieved memories.

When we challenged participants' memories, they showed significant declines both in belief and recollection scores, but belief scores dropped even more. This means that participants had lower beliefs that the pictures had appeared and thus started to doubt their own memories. This is consistent with previous studies that induced nonbelieved memories in the laboratory (Li et al., 2020; Mazzoni et al., 2014; Otgaar et al., 2018; Wang et al., 2019a, b) where the belief scores decreased significantly when facing challenges. Our findings are related to recent research showing that bizarre memories (which are also distinctive) can also result in nonbelieved memories. Specifically, Li and colleagues (2020) used social feedback to reduce participants' belief in bizarre experiences (e.g., "*balance the spoon on your nose*").

In our experiments, not only the belief score but also the recollection score dropped significantly after being challenged. This may further explain that when people experience a negative event, they are less willing to disclose the event (McNally, 2003). Autobiographical memory literature has shown that unpleasant life events are more difficult to recall than pleasant ones (Mather, 2006). Out of self-protection, people selectively ignore memories of certain events (e.g., traumatic experiences; Sedikides & Green, 2009). The memory neglect model (Sedikides & Green, 2004) may be used to explain why people selectively ignore certain memories. This model describes the self-concept as a rich, well-organized, predominantly positive mental representation that is affected by emotion and motivation (McConnell & Strain, 2007; Tracy & Robins, 2007). The aim of the model is to explain how memory dynamically responds to self-threatening information (Sedikides & Green, 2009). When these reluctantly recalled negative pictures are given false social feedback, telling participants they had not seen the pictures, it also seems to give them a reason to refuse to disclose these negative experiences.

In the current study, we used false social feedback to reduce participants' beliefs and recollections of the presented pictures. Although we found belief ratings to drop after providing feedback, a question is whether our findings might be related to participants' compliance with the experimenter's instructions. Wang and colleagues (2017) examined whether compliance was related to nonbelieved memories but did not find a significant correlation. Nonetheless, caution is needed when interpreting the reduction of beliefs or recollection due to challenges. It might still be the case that the reductions in belief and recollection merely reflected participants' compliance to the challenges provided by the experimenter instead of true decreases in belief and recollection. In our study, however, participants did not change their beliefs/recollections for all of the challenges. If compliance actually drove the effect, we should have observed a decrease in beliefs/recollections for each item that was challenged, but this is not what we observed. Future research might focus on whether any individual differences such as compliance might play a role in belief reduction. One option is to measure participants' compliance tendency or experimentally manipulate factors related to compliance when providing feedback such as providing high credible or low credible feedback. If our results are merely due to compliance, it would not matter whether feedback is given from a low or high credible source.

In addition to investigating participants' belief and recollection scores, we also used the VAS score to estimate the

impact of the challenge on the emotional state of the participants. Since emotional states can be influenced by beliefs (Blanchette & Caparos, 2013; Frijda et al., 2000; Kneeland et al., 2016), we hypothesized that when participants stopped believing that they had experienced a negative event (i.e., had not viewed these negative pictures), their emotional state would improve. However, no notable significant changes in the emotional state were found in our experiments. This may be because the negative stimuli were not strong enough to trigger a more robust emotional response from the participants, or possibly due to the interplay of emotional states induced by viewing different kinds of pictures simultaneously. Additionally, the interpretation of reduced belief scores by participants may suggest that they perceive the challenge as indicating slight variations rather than denying the existence of negative pictures. It is important to note that we only challenged some of the negative pictures. Even if challenging negative experiences would have an effect on mood, it might be necessary to challenge all of the traumatic experiences (and not only some of them) to demonstrate such an effect. To better investigate whether challenging memories have an effect on negative emotions due to negative events, future experiments may examine whether stronger challenges (e.g., repeatedly challenging memories) might change people's emotional state.

Taken together, the purpose of our experiments was to test participants' production of nonbelieved memories for negative experiences. We showed the relative ease by which nonbelieved memories for negative experiences can be elicited. Although negative experiences are difficult or even impossible to forget (e.g., Christianson & Loftus, 1987), we did show that beliefs about negative pictures can readily be reduced. Our work is informative as it might elucidate why some individuals with negative memories believe less in these memories at a later stage, thereby claiming that these events never happened.

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Data Availability All data are available at https://osf.io/jdu45/.

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