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BRIEF REPORT

Memory suppression can help people "unlearn" behavioral responses—but only for nonemotional memories

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Abstract When encountering reminders of memories that we prefer not to think about, we often try to exclude those memories from awareness. Past studies have revealed that such suppression attempts can reduce the subsequent recollection of unwanted memories. In the present study, we examined whether the inhibitory effects extend even to associated behavioral responses. Participants learned cue–target pairs for emotional and nonemotional targets and were additionally trained in behavioral responses for each cue. Afterward, they were shown the cues and instructed either to think or to avoid thinking about the targets without performing any behaviors. In a final test phase, behavioral performance was tested for all of the cues. When the targets were neutral, participants' attempts to avoid retrieval reduced accuracy and increased reaction times in generating behavioral responses associated with cues. By contrast, behavioral performance was not affected by suppression attempts when the targets were emotional. These results indicate that controlling unwanted recollection is powerful enough to inhibit associated behavioral responses—but only for nonemotional memories.

Keywords Memory suppression · Emotion · Behavioral memory · Think/no-think

One of the fundamental questions in memory research is how to enhance memory and reduce forgetting. However, forgetting is not always bad. Intentional forgetting is an important ability when previously learned information is no longer valid. The ability to forget memories deliberately may also be important for mental health. For example, posttraumatic stress disorder and depressed patients often suffer from intrusive recall of negative memories (Ehlers & Clark, 2000; Williams & Moulds, 2008), and the current memory of a traumatic event determines symptoms more than the event itself (Rubin, Berntsen, & Bohni, 2008).

One commonly used strategy to deliberately forget memories is to exclude unwanted memories from awareness. Past research using the think/no-think (TNT) paradigm demonstrated that such inhibitory control can indeed lead to forgetting (Anderson & Levy, 2009). In this paradigm, participants first learn cue–target pairs until they can recall the target when given the cue as a reminder. Participants are then shown the cues without the targets. For some cues, they are asked to retrieve the associated target ("think" items), whereas for other cues they are asked not to think about the target ("no-think" items). Finally, participants are asked to recall associated targets for all cues. Typically, people have more difficulty recalling "no-think" items than recalling "think" items. When the TNT manipulation is repeated intensively, "no-think" items are even less likely to be recalled than control items whose cues are not shown during the TNT manipulation (Anderson & Green, 2001). Previous studies also extended the paradigm to emotional memories and revealed mostly similar suppression effects for emotional and nonemotional memories (Depue, Banich, & Curran, 2006; Depue, Curran, & Banich, 2007; Joormann, Hertel, Brozovich, & Gotlib, 2005; Marx, Marshall, & Castro, 2008; Murray, Muscatell, & Kensinger, 2011).

However, avoiding conscious recollection of unwanted memories may not be sufficient to control memory. For example, emotionally negative events are often accompanied with certain behavioral responses that do not occur for neutral events (e.g., escape behaviors; Lang, Bradley, & Cuthbert, 1998). When encountering cues associated with past traumatic

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events, those cues might not only remind people of their associated negative events, but also activate unwanted behavioral responses associated with the cues. Thus, inhibiting associated behavioral responses also seems to be important in life. Yet, past studies on intentional forgetting have predominantly focused on the effects on conscious recollection. Therefore, it is not clear whether controlling unwanted recollection can suppress associated behavioral responses.

The main purpose of the present study was to address whether suppressing unwanted recollection can have inhibitory effects on associated behavioral responses. Given that similar brain areas are involved when suppressing retrieval and inhibiting behaviors (Anderson et al., 2004; Simmonds, Pekar, & Mostofsky, 2008), one might expect that people's efforts to avoid retrieval inhibit not only conscious recollection, but also associated behaviors. However, the memory representations associated with behaviors depend on different brain mechanisms than do those triggering recollection (Henke, 2010; Poldrack & Packard, 2003; Squire, 2004). Thus, an alternative prediction would be that retrieval suppression reduces conscious recollection, but leaves associated behavioral responses intact.

The second goal of the present study was to address the effects of negative emotion. Because involuntary recall of negative memories can impair mood (Berntsen, 2001), intentional forgetting may be especially desirable for negative memories. Therefore, we examined whether retrieval suppression has similar effects on associated behavioral responses across emotionally negative versus nonemotional associations.

To address these two goals, we had participants learn to associate neutral objects with negative or neutral pictures, and further practice a behavioral response for each object. The behavioral responses learned for the objects were determined by the emotional quality of the pictures. This allowed us to introduce behavioral reactions specific for negative and neutral events in a controlled way, making our experiment setting similar to many real-life situations, as emotional and neutral events are usually paired with different behavioral responses in life. Participants were then shown the objects and told to think or not to think about the associated pictures, without performing any behaviors. Finally, behavioral performance was tested for all of the object cues. If retrieval suppression can successfully inhibit associated behavioral responses, participants should be slower and less accurate in producing learned behavioral responses for cues in the no-think condition than in the control condition.

Method

Participants

Thirty-six undergraduates (28 females, eight males; M_{age} = 22.4, SD = 4.6) participated for course credit.

Materials

The materials involved 48 negative pictures. Each negative picture was yoked with a visually similar, but less arousing, neutral picture (Mather & Nesmith, 2008). The resulting 48 pairs were grouped into three sets of 16 pairs. Each set was assigned to one of three conditions (think, no-think, or control); the assignment was counterbalanced across participants. Each participant was shown only one picture from each pair, resulting in eight negative and eight neutral pictures in each condition; the version that was shown was also counterbalanced across participants. These pictures were randomly paired with 48 neutral objects obtained from previous research (Snodgrass & Vanderwart, 1980). During the study, the pictures served as targets, and the objects served as cues.

Procedure

The experiment involved a learning phase, a TNT phase, and a final test phase. In all phases, trials were presented in a random order, irrespective of picture valence and conditions.

Learning phase First, participants were shown 48 object–picture pairs (each for 6 s) and told to remember them. Each pair was shown once. Next, they learned a behavioral response for each object (unspeeded behavioral-training phase). During each trial, participants were shown one of the 48 objects without the associated picture and told to press a left or right key, depending on the valence of the associated picture; the assignments of keys to negative and neutral valence were counterbalanced across participants. Participants then viewed the associated picture for 2 s as feedback. To strengthen the cue–response associations, the unspeeded training phase was repeated three times. In a subsequent speeded behavioral-training phase, participants were shown each object again and asked to press the correct key as quickly and accurately as possible without subsequent feedback pictures. The speeded training phase was also repeated three times.

TNT phase Participants viewed each object for 6 s with either a red or a green frame. They were told to think of the associated picture when the frame was green (think condition) and to prevent the associated picture from coming to mind when the frame was red (no-think condition). This procedure was repeated five times. Objects assigned to the control condition were not used in this phase.

Final memory tests Participants' memory was tested for all objects, irrespective of condition. First, participants were asked to press the correct key for each object as quickly and accurately as possible (response memory test). The objects disappeared upon response or when participants did not press a key within 2 s. Next, participants were instructed to describe the associated picture for each object without any time restriction (pair memory test).

Results

Learning phase

Response accuracy improved from the first ($M = .91$) to the final ($M = .95$) round in the speeded training phase, $F(1, 35) = 22.17$, $p < .001$, $\eta_p^2 = .39$. Reaction times (RTs) also decreased from the first ($M = 865$ ms) to the final ($M = 675$ ms) round, $F(1, 35) = 174.65$, $p < .001$, $\eta_p^2 = .61$. Although participants responded faster to negative than to neutral pairs in the first round ($M_{neg} = 833$ ms, $M_{neut} = 896$ ms), $F(1, 35) = 9.72$, $p < .05$, $\eta_p^2 = .15$, neither accuracy ($M_{neg} = .96$, $M_{neut} = .95$) nor RT ($M_{neg} = 664$ ms, $M_{neut} = 686$ ms) showed significant valence effects in the final round, Fs$(1, 35) = 1.63$ and 1.19, $ps > .20$. Since we aimed to examine TNT effects on learned memories in the present study, for the following analyses, we excluded any objects for which participants failed to press the correct keys in the final round of the training phase.

Target recollection

A 3 (condition: think, no-think, control) × 2 (valence: negative, neutral) analysis of variance (ANOVA) was performed on the correct recollection rates from the pair memory test. We found a significant effect of condition, $F(2, 70) = 3.96$, $p < .05$, $\eta_p^2 = .12$. Neither the effect of valence, $F(1, 35) = 0.20$, nor the Valence × Condition interaction, $F(2, 70) = 0.37$, was significant ($ps > .60$). In line with previous findings that people can control unwanted recollection for both emotional and nonemotional memories (e.g., Murray et al., 2011), a post-hoc Tukey's test revealed impaired recall in the no-think condition ($M_{neg} = .58$, $M_{neut} = .57$) as compared with the think condition ($M_{neg} = .67$, $M_{neut} = .63$), $t = 2.67$, $p < .05$, $d = 0.51$. Performance did not differ significantly between the control condition ($M_{neg} = .59$, $M_{neut} = .59$) and the other two conditions, ts = 2.15 and 0.52, $ps > .05$ (Tukey), which is a typical finding for smaller numbers of TNT repetitions (e.g., Anderson & Green, 2001).

Behavioral memory

Next, we examined the effects of the TNT manipulations on performance in the response memory test. Since slower responses might reflect a random guess in the response memory test, outlier RTs (two *SD*s above the median for each condition for each participant) were excluded from the analyses in this section.[1]

Accuracy A 3 (condition) × 2 (valence) ANOVA was performed on accuracy in the response memory test. The accuracy in the speeded training phase was included as a covariate. This analysis revealed a significant Condition × Valence interaction (Fig. 1a), $F(2, 70) = 4.66$, $p < .05$, $\eta_p^2 = .10$. Subsequent analyses found a significant condition effect for neutral pairs, $F(1, 70) = 4.53$, $p < .05$, $\eta_p^2 = .11$. When associated pictures were neutral, participants were less accurate in the no-think condition ($M = .93$) than in the control ($M = .98$) and think ($M = .97$) conditions, ts = 2.67 and 2.51, $ps < .05$ (Tukey), ds = 0.37. In contrast, accuracy for the negative pairs was not influenced by the TNT manipulation, $F(1, 70) = 1.08$, $p > .30$.

Reaction times To examine the TNT effects on RTs in the response memory test, a hierarchical linear model analysis (Raudenbush & Bryk, 2002) was employed, with each item as a level-1 unit and each participant as a level-2 unit. The dependent variable was the RT from each correct response for each participant during the response memory test; incorrect responses were not included in this analysis. Predictor variables were condition, valence, the Condition × Valence interaction, and the RT from the speeded training phase for each item.

We found significant effects of condition and of RT from the training phase, Fs$(2, 1427) = 7.76$ and 60.71, $ps < .01$, R^2s = .06 and .02. Furthermore, a significant Condition × Valence interaction emerged (Fig. 1b), $F(2, 1427) = 4.58$, $p < .05$, $R^2 = .05$. For neutral pairs, RTs showed a significant condition effect, $F(1, 1427) = 11.72$, $p < .01$, $R^2 = .03$; participants were slower in the no-think condition ($M = 677$ ms) than in the control ($M = 638$ ms) and think ($M = 615$ ms) conditions, ts = 2.85 and 4.54, $ps < .05$ (Tukey) , ds = 0.29 and 0.49. In contrast, RTs were not affected when pairs were negative, $F(1, 1427) = 0.61$, $p > .50$.

Effects of target recollection on behavioral memories

The results above suggest a possible dissociation between picture memories and behavioral responses; whereas the pair memory test showed similar patterns in the recollection of emotional and nonemotional pictures, the response memory test revealed that retrieval suppression inhibited behavioral responses associated with nonemotional pairs only. This dissociation in outcomes argues against the possibility that the accessibility of behavioral responses depends directly on the accessibility of the picture memories.

[1] Both RTs and accuracy showed similar results, even when excluding additional trials with slow reaction times (>1,000 ms; 3.45 % of all trials).

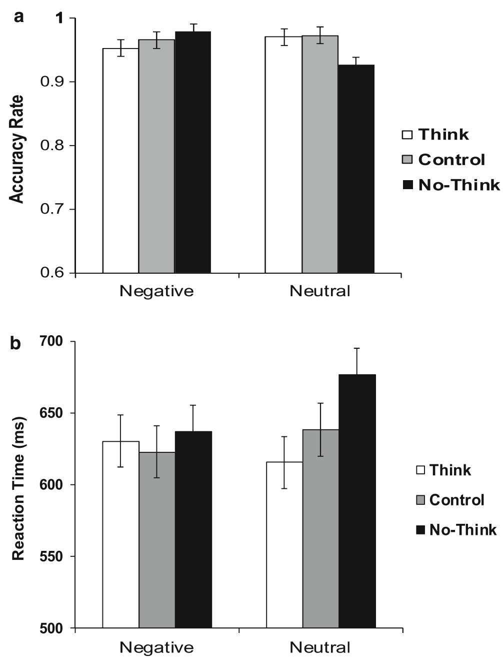

Fig. 1 Effects of retrieval suppression on performance in the object–response memory test. **a** Accuracy. Retrieval suppression reduced accuracy in producing object–response associations when associations were neutral, but not when they were emotional. **b** Reaction times. Similarly, participants' retrieval suppression attempts slowed reaction times to produce the correct object–response associations when the associations were neutral, but not when they were emotional. Error bars represent standard errors.

To further investigate the relationship between the two measures, trials were categorized on the basis of the pair memory performance: trials in which the participants could successfully remember the associated pictures in the pair memory test (remembered pairs), and trials in which they failed to remember the associated pictures (forgotten pairs). We then examined the TNT effects on the response memory test, while including the pair memory performance as an additional independent variable. This did not alter the significant Valence × Condition interactions in the response memory test for either the RTs, $F(1, 1421) = 5.02$, $p < .01$, $R^2 = .05$, or accuracy, $F(2, 70) = 3.82$, $p < .05$, $R^2 = .09$. Participants were less accurate in the no-think than in the control condition when the associated pictures were neutral, irrespective of pair memory test performance: remembered pairs ($M_{con} = .99$ vs. $M_{NT} = .95$), $F(1, 66) = 4.45$, $p < .05$, $R^2 = .02$, and forgotten pairs ($M_{con} = .96$ vs. $M_{NT} = .91$), $F(1, 53) = 3.13$, $p = .08$, $R^2 = .01$. In contrast, when the associated pictures were negative, neither the remembered ($M_{con} = .99$ vs. $M_{NT} = .98$) nor the forgotten ($M_{con} = .95$ vs. $M_{NT} = .98$) pairs showed significant differences between the no-think and control conditions, $F(1, 66) = 0.26$, $F(1, 53) = 0.57$, $ps > .40$. Likewise, when pictures were neutral, the RTs were slower in the no-think than in the control condition for both remembered pairs ($M_{con} = 641$ ms vs. $M_{NT} = 679$ ms), $F(1, 547) = 4.98$, $p < .05$, $R^2 = .01$, and forgotten pairs ($M_{con} = 641$ ms vs. $M_{NT} = 686$ ms), $F(1, 360) = 4.00$, $p < .05$, $R^2 = .04$. In contrast, when the associated pictures were negative, neither the remembered ($M_{con} = 617$ ms vs. $M_{NT} = 642$ ms) nor the forgotten ($M_{con} = 631$ ms vs. $M_{NT} = 633$ ms) pairs showed significant differences, $F(1, 547) = 1.96$, $F(1, 360) = 0.00$, $ps > .15$.

Discussion

Previous studies revealed that excluding unwanted memories from awareness can inhibit subsequent recollection of the memories (Anderson & Levy, 2009). The present study revealed that the suppression effects can extend to associated behavioral responses. After participants prevented the retrieval of target pictures, they showed reduced accuracy and increased RTs in generating behavioral responses associated with the cues when the cue–target associations were neutral. Similar effects were observed irrespective of the object–picture pair memory performance. Thus, it is unlikely that the decreased behavioral performance in the no-think condition was mediated by the amount of forgetting of target pictures. These findings suggest that excluding unwanted memories from awareness can have inhibitory effects even on associated behavioral responses.

Past studies have revealed that brain regions implementing the suppression of conscious recollection are also associated with the inhibition of behavioral actions (Anderson et al., 2004; Simmonds et al., 2008). The behavioral suppression effects observed in the present study may reflect this common neural mechanism. That is, when one attempts to exclude unwanted memories from awareness, this might activate general inhibitory control mechanisms that effectively impair not only conscious recollection of the memories, but also related behavioral responses.

The present study also revealed an important boundary condition in this behavioral suppression effect. That is, retrieval suppression inhibited associated behavioral responses only when memories were neutral, but not when memories were emotional. The lack of a suppression effect for emotional behavioral responses contrasts with past findings that retrieval suppression is equally effective for recollection of emotionally negative as for nonemotional items (Depue et al., 2006; Joormann, Hertel, LeMoult, & Gotlib, 2009; Lambert, Good, & Kirk, 2010; Murray et al., 2011). This dissociation may be explained by emotional memory enhancement effects (Mather & Sutherland, 2011): People are more likely to remember emotional than nonemotional events (LaBar & Cabeza, 2006). Thus, retrieval suppression should be more demanding for emotional than for nonemotional memories (Butler & James, 2010; Nowicka, Marchewka, Jednorog, Tacikowski, & Brechmann, 2011 see also Nashiro, Sakaki, Huffman & Mather, 2013). Therefore, when one recruits cognitive control to avoid retrieval of emotional memories, most of the cognitive resources might be dedicated to regulating recollection of the particular memories (emotional pictures, in our study). This should leave fewer resources available to inhibit related representations, thus producing weaker suppression effects on related reactions such as behavioral responses.

Some questions remain for future research. First, in the present study we employed fewer TNT repetitions than had past studies (5 vs. 12–16 times). Although this does not weaken our conclusion that behavioral responses associated with negative memories are less likely to be forgotten than are those associated with neutral memories, it might be possible that behavioral responses for emotional memories can show forgetting after more intensive TNT repetitions.

Second, in the present study, participants learned behavioral responses for each of the cues on the basis of the valence of the associated pictures. Thus, we introduced behavioral responses so that they were specific to the emotional quality of a pair. This allowed us to examine inhibitory control of behavioral responses in a situation similar to many real-life behaviors, as emotional cues often evoke unique behavioral responses not associated with neutral cues. However, it is possible that the lack of behavioral suppression effects for emotional cues observed in this study may not be directly attributable to a failure in suppressing behavioral responses, but may rather be mediated by a more general failure in suppressing the associations between cues and emotional valence (negative or neutral). Thus, one important avenue for future research would be to examine the effects of emotion and thought suppression attempts on behavioral responses that are independent of emotional valence.

Conclusions

Despite the fact that human memories involve multiple aspects and are expressed in a number of different ways, previous studies on memory suppression have predominantly focused on the recollection of item memories. Thus, it has not been clear whether and how one can control other aspects of memories, such as behavioral responses or general semantic associations. In the present study, we examined the inhibitory control of learned behavioral responses and revealed that cognitive control has different impacts on two memory aspects: behavioral responses and item memories. That is, whereas item memory recollection was similar across emotional and nonemotional memories, we found that retrieval suppression can successfully inhibit behavioral responses only for neutral memories. In addition, the suppression effects in behavioral responses were observed irrespective of the item memory performance. Further studies along this line may provide a better understanding of memory suppression mechanisms, as well as implications about how to control memories and prevent intrusive recall of stressful experiences in life.

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