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# Positive affect facilitates the effect of a warning on false memory in the DRM paradigm

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Increasing evidence that positive affect enhances associative processing has lent weight to the idea that positive affect increases false memory for information that is thematically interrelated. Using the Deese–Roediger–McDermott paradigm, we examined whether mild positive affect facilitates monitoring processes in modulating false memory for associate words. When participants in the warned condition – in contrast to those in the unwarned condition – were overtly warned about possible false recognition of the critical lure, we found that positive affect, compared to neutral affect, significantly enhanced monitoring through a warning and reduced false recognition. Signal detection analyses suggest that when a warning is provided, positive affect enhances sensitivity to discriminate list items from critical lures, but it does not shift the overall decision criterion. Taken together, we conclude that positive affect facilitates the effect of a warning in reducing false memories for semantic associates.

**Keywords**: positive affect; false memories; DRM paradigm; monitoring processing

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False memory refers to the recollection of an event – or the details of an event – that did not occur (Loftus, 1997). These memory errors reflect the operation of associative memory processes, which take place in an existing relationship between a stimulus and a response (for a review, see Gutchess & Schacter, 2012). Given that positive affect promotes associative processing (for a review, see Isen, Daubman, & Nowici, 1987), the question arises whether mild positive affect gives rise to false memory. A vast body of empirical evidence suggests that mild positive affect, induced through humor or a small gift, enhances broad associative activation through effective access to, and integration of, extensive cognitive material (e.g. Mackie & Worth, 1989). Moreover, the affect-as-information (AAI) theory (e.g. Schwarz, 1990) also postulates that positive affect signals that the environment is safe, and therefore promotes heuristic and gist-based (i.e. relational) processing. These views have led to the idea that positive affect is likely to create false memory when remembering multiple concepts that are thematically related because positive affect promotes the gist-based representation of semantically related concepts. Consistent with this idea, Bless et al. (1996) have demonstrated that induced positive affect, compared to negative affect, increases false recognition (i.e. memory intrusion) of typical information not presented in the script of an everyday situation (e.g. going out for dinner). They contend that positive affect increases false memory by facilitating reliance on well-learned general knowledge structures, such as scripts and routines (schemata), which allow simplified and efficient processing by freeing up processing resources – but at the expense of rendering processing more error prone. Despite these assumptions about a link between positive affect and heuristic and gist-based processing, there are three classes of challenges to the contention that positive affect promotes memory errors in learning prototypical or semantically related concepts. First, the assumption that positive affect induces reliance on general knowledge is at odds with evidence that positive affect enhances originality and innovative thinking (Isen, 2000).[1] The originality and innovation observed in people in positive mood is likely achieved by less reliance on well-learned, typical ways of thinking, as opposed to the greater reliance posited by Bless et al. (1996). This is because schema-based knowledge tends to routinize thinking and impedes access to unusual cognitive material (Rowe, Hirsh, & Anderson, 2007). Second, reliance on schemata is considered disadvantageous in more complicated domains (e.g. creative problem solving, negotiation, and decision-making), in which focusing on atypical details can be important (Rowe et al., 2007). At the same time, however, several studies have demonstrated the beneficial effects of positive affect on such processes (e.g. Breslin & Safer, 2011; Carnevale & Isen, 1986; Staw & Barsade, 1993). And third, any processing resources allegedly freed up by positive affect could be used for activities other than inferential processing, such as greater contextual encoding, item-specific rehearsal, retrieval tagging, and monitoring – all of which be expected to decrease, not increase, false memory. For these reasons, the claim that positive affect increases false memory warrants further research.

### *False memory in the Deese–Roediger–McDermott paradigm*

Because no clear link has been established between positive affect and false memory, our understanding is still poor. We set out to investigate the association, if any, by using the well-known Deese–Roediger–McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), which allows for greater control over affective valence without raising doubts about the validity of recall of naturalistic events. In the DRM paradigm, participants are presented with multiple lists of semantic associates (for example, ‘snow,’ ‘winter,’ ‘ice,’ and so on) that are related to a non-presented critical item (in this case, ‘cold’). Typically, participants erroneously endorse the critical lure as frequently as the studied word (see Roediger, McDermott, & Robinson, 1998, for a review).

Several theoretical accounts have been advanced to explain the phenomenon of false memory. The *spreading- activation* theory posits that false memory occurs when critical items are automatically activated due to the excitation of related nodes within a semantic network (Collins & Loftus, 1975). The *activation-monitoring* theory postulates that the activation process triggers false memory by spreading activation to related lures, but subsequent monitoring processes play a role in determining false memories (Roediger, Watson, McDermott, & Gallo, 2001). Similarly, the *fuzzy-trace* theory posits that false memory occurs when participants favor gist-based representation, while verbatim-based (i.e. specific properties of stimuli) retrieval, in response to a lure, may attenuate false memories.

Using the DRM paradigm, Storbeck and Clore (2005, 2011) first found that negative affect, compared to both positive affect and the control condition, reduces false memory by promoting item-specific processing – that is, processing the properties of individual items not shared with other items; this is especially evident during encoding. It should be noted, however, that in both of Storbeck and Clore’s studies, the positive-affect group did not differ from the control group in false memory. These findings contradict the prevailing idea that positive affect promotes false memory because of its facilitating role in associative processing and gist-based heuristics. They also offer two important suggestions. The first is that any process responsible for the difference between the positive and negative affect condition should be more appropriately attributed to negative affect than positive affect. Second, the finding that positive affect does not enhance false memory – compared to neutral affect – suggests the possibility that positive affect may influence other counteractive processes such as monitoring, which may offset the tendency to increase false memory. We further explain below why we believe that monitoring may serve as a potential counteractive process that would influence the previously proposed relationship between positive affect and false memory.

### *Positive affect and the monitoring process*

Our study’s aim was to determine whether positive affect modulates false memories through improved monitoring, which can potentially override any setback that results from activating the critical item during encoding processing. One way to study the effects of positive affect on spontaneous monitoring is to use explicit warnings about the false-memory phenomenon (i.e. memory intrusion of the critical item). Research using the DRM paradigm has indicated that a warning about the false-memory effect given before the study significantly reduces false memory by enabling participants to monitor and identify the critical item during presentation of the study lists; this is known to be the most effective strategy to reduce false memory (Gallo, Roediger, & McDermott, 2001; McCabe & Smith, 2002). Therefore, if positive affect provides a more favorable condition – in which people are likely to engage in active and rigorous monitoring – positive affect should substantially reduce false memory through the promotion of monitoring behavior (Rowe et al., 2007).

Some empirical evidence suggests the relation of positive affect to a set of higher order cognitive processes that are believed to be related to monitoring abilities. For instance, the literature on positive affect has suggested that it facilitates higher order controlled processes, such as cognitive set switching (e.g. Isen & Schmidt, 2007), working memory (Carpenter, Peters, Vastjfall, & Isen, 2013; Yang, Yang, & Isen, 2013), task switching (Yang & Yang, 2014), and attention deployment (Derryberry, 1993), all of which implicate controlled processing that can be employed to support careful monitoring in the DRM task. The importance of attentional control has consistently been highlighted in the DRM literature. For example, Peters et al. (2008) have demonstrated that manipulation of attentional control profoundly influences participants’ susceptibility to false memories in the DRM paradigm. They suggest that a breakdown in attentional control during encoding undermines monitoring vigilance, and thus leads to increased reliance on familiarity-based processes.

Similarly, Leding (2012) found that individuals with low working memory capacity experience greater false memories precisely because they are less able to engage in source monitoring. In light of these results, it is possible that either enhanced attentional control or working memory capacity, which improve in a positive affect state, can contribute by way of a warning to monitoring abilities that help suppress false memories (Gray, 2001; Yang et al., 2013).

In our study, we hypothesized that if positive affect facilitates the effect of a warning, especially through improved (spontaneous) monitoring, it should also result in a greater decline in false memory than neutral affect because monitoring should help in identifying gist information, which is automatically activated during initial encoding. We manipulated a warning (warning vs. no warning), and participants in the warned group – in contrast to those in the unwarned condition – were twice told not to 'fall prey' to critical lures. This was accomplished through an overt warning about possible false recognition of the critical item. The warning was given before the study and again before retrieval (i.e. the recognition test).

## Method

### *Participants*

Seventy-eight undergraduates (male = 25) from a northeastern US university participated in the study in exchange for extra credit. Participants were randomly assigned to one of four conditions: warned-positive affect (n = 21), warned-neutral affect (n = 19), unwarned-positive affect (n = 20), and unwarned-neutral affect (n = 18).

### *Design*

The ITEM (semantically associated list items and non-presented critical lures) was manipulated within participants. AFFECT (positive and neutral) and WARNING (warning and no warning) were manipulated between participants.

### *Materials*

Two affect manipulation checks were employed. The Remote Associates Test (RAT; Mednick, 1962) served as an unobtrusive manipulation check on induced positive affect immediately after induction, and a single-item explicit check was administered at the end of the study to ensure that the induced mood had remained effective until the end of the study.

Despite the assumed effectiveness of an explicit manipulation check that asks participants to indicate the degree of their mood, following the gift with an obvious question about mood could cause participants to be suspicious of the experimenter's intent in giving them the gift – which, in turn, could dispel the induced feeling state (Isen & Erez, 2007). Accordingly, it may be more appropriate to employ an implicit manipulation check. The RAT can be useful for such a purpose because (a) the literature has documented that mild positive affect improves performance on the RAT (for a review, see Isen, 2008) and (b) successful performance on the RAT is believed to rely on cognitive abilities such as verbal fluency, associative learning, and insightful problem solving (e.g. Ansburg & Hill, 2003; Wiley & Jarosz, 2012), all of which have been shown to improve under positive affect (for a review, see Ashby, Isen, & Turken, 1999). We therefore expected that participants in the positive-affect condition would perform better on the RAT than those in the control condition.

In the RAT, a person is required to think of a word in relation to each of three other words presented; for instance, cadet, capsule, and ship (answer: space). In all, 21 RAT items were taken from Bowden and Jung-Beeman's (2003) normative data. These items were selected on the basis of a difficulty score determined by the percentage of participants who solved a given item within 15 s. The average difficulty score was 51%. This is optimal psychometrically because a score of 50% maximizes statistical power in detecting correlations.

Eighteen lists of semantic associates were selected from the norms published by Stadler, Roediger, and McDermott (1999). The lists were divided into three sets; each contained six lists of semantic associates, with their normed false-recall rates matched (SET A = 74.6%, SET B = 75%, SET C = 74.8%). The lists within each set were counterbalanced to function in the recognition test as either list items, critical lures, or baseline items. Lists that were directly related to emotion (e.g. the 'anger' list) were excluded because the emotional content of stimuli influences the distribution of attention and controlled processing (Kensinger & Corkin, 2003). Each of these lists consisted of the top 12 ranked associates of a given critical item; for instance, 'nose,' 'breathe,' 'sniff,' 'aroma,' 'hear,' 'see,' 'nostril,' 'whiff,' 'scent,' 'reek,' 'stench,' 'fragrance,' (Critical item: smell). None of the critical items appeared in any of the study lists. The recognition test contained 72 items; 36 had been presented in the study phase and the remainder had not. The 36 studied items were sampled from serial positions – 1st, 8th, and 10th – on each of the studied lists. The remaining 36 nonpresented items included 12 critical items – one from each of the studied lists – and 24 new items from the baseline lists.

### *Procedure*

*Affect induction*

Positive affect was induced by giving participants a small bag of candy, attractively tied with a ribbon, as a token of appreciation for agreeing to participate. Participants were asked to put it away with their books and take it with them when they left the lab – i.e. no participant ate the candy during the session. Previous studies have shown that this method can effectively induce mild  positive affect sufficient to influence cognition in both students and professionals, such as physicians (e.g. Estrada, Isen, & Young, 1997). Participants in the neutral condition did not receive a gift and were unaware of its presence, as an instruction was given to each individual while they were in the separate reception room. Equivalent levels of interaction between participants and experimenter were ensured by following the same behavioral protocol (e.g. the same verbal expression of thanks).

*The RAT*

The RAT was then administered as an unobtrusive manipulation check. Participants were seated individually in front of a computer and wore headphones. Instructions for the RAT and two examples were presented on the computer screen, and participants were given a worksheet on which they were to answer as many items as they could within 3 min. When the time elapsed, a beep went off in the headphone. The next phase was modeled after the DRM paradigm.

*The DRM paradigm*

Prior to the study phase, participants in the warned condition – in contrast to those in the unwarned condition – were explicitly warned about the false-memory phenomenon and strongly encouraged to increase vigilant monitoring to avoid falsely encoding critical items. For each trial, the fixation signal appeared on the computer screen for 500 ms and the study item was presented for 1500 ms, followed by a blank screen for 1000 ms. As suggested by McDermott and Watson (2001), we chose this duration (3000 ms) because it was long enough for the participant to distinguish true memory (for the studied item) from false memory (for the critical item). Each list was separated by a visual prompt (‘NEW LIST’) for 3 s. The study phase took approximately 7 min and was followed by a simple math task as a filler task for 3 min.

*Recognition test*

Prior to the recognition-test phase, the warning was repeated to remind participants in the warned group of the false-memory phenomenon and to strongly encourage them to avoid falsely recognizing critical items. The warning was not given to the unwarned group. In the recognition test, each test item was preceded by the fixation point for 300 ms, and participants were asked to decide whether the test word had been presented in the study phase (‘Old’) or not (‘New’). The test phase took approximately 3 min.

*Post-task affect manipulation check*

After the recognition test, all participants completed a funnel questionnaire, using a 9-point scale that was designed to check the post-task ratings of induced affect (pleasantness), arousal, perceived importance of the task, and enjoyment. The post-task check on induced affect was administered approximately 13 min after the induction of positive affect, the duration of which falls within the typical time window for an induced effect to remain effective. Additional questions were included to probe participants’ awareness of the research hypotheses, suspicions about the study, and miscellaneous matters such as any previous experience or familiarity with the study.

## Results

### *Affect manipulation check*

An independent-samples t-test of the mean number of correct items on the RAT showed that the positive-affect group performed significantly better than the neutralaffect group, $t(76) = 3.72$, $p < 0.01$, Cohen’s $d = 0.84$. This result demonstrates that participants in the positiveaffect condition felt more pleasant than those in the control condition and that the method used to induce positive affect had been effective.

An independent-samples t-test was performed on post-task ratings of induced affect (Table 1). Consistent with the result obtained from the RAT, we found that the positive-affect group still felt more pleasant than the neutral- affect group at the end of the task, $t(76) = 2.39$, $p = 0.02$, Cohen’s $d = 0.54$, but arousal differences did not emerge by the end of the task, $t(76) = 1.42$, $p = 0.16$. This suggests that the method for inducing positive affect was effective and that the induced mood persisted until the end of the study.

### *Recognition*

A mixed-factor repeated-measures ANOVA by ITEM (list, critical), AFFECT (positive, neutral), and WARNING (warning, no warning) was performed on mean probability of recognition. We found two main effects of WARNING and ITEM. The main effect of WARNING was that the warned group ($M = 60.8$) showed significantly lower recognition rates than the unwarned group ($M = 73$), $F(1, 74) = 23.1$, $p < 0.001$, $\eta_2 = 0.14$. The main effect of ITEM showed significantly greater true recognition for studied list items ($M = 73.5$) than false recognition for critical lures ($M = 59.9$), $F(1, 74) = 21.03$, $p < 0.001$, $\eta_2 = 0.19$. Given the literature that has typically shown comparable rates of recognition for both the list item and critical lure, the main effect of ITEM indicates enhanced monitoring, which signals the ability to differentiate the critical lure from the studied item. In addition, we found a significant interaction between

Table 1. Performance on the RAT, self-reported ratings of pleasantness, arousal, enjoyment, and task importance, and parameters from the SDT analysis as a function of induced affect and warning.

| | Warned ($n = 40$) | | | Unwarned ($n = 38$) | | |
|---|---|---|---|---|---|---|
| | Positive ($n = 21$) | Neutral ($n = 19$) | $p$ | Positive ($n = 20$) | Neutral ($n = 18$) | $p$ |
| *Induced affect check* | | | | | | |
| RAT | 12.3 (3.0) | 9.1 (3.6) | 0.003 | 11.1 (3.3) | 8.5 (4.1) | 0.04 |
| *Funnel questionnaire* | | | | | | |
| Pleasantness | 6.4 (1.0) | 5.7 (1.3) | 0.05 | 5.8 (1.8) | 4.4 (2.5) | 0.05 |
| Arousal | 4.3(1.5) | 3.7 (1.2) | 0.21 | 4.6 (.99) | 4.4 (.97) | 0.51 |
| Enjoyment | 5.4 (1.5) | 5.4 (1.8) | 0.98 | 5.5 (1.8) | 4.4 (1.7) | 0.06 |
| Importance | 5 (1.7) | 4.7 (1.5) | 0.61 | 5.8 (1.8) | 4.4 (2.5) | 0.057 |
| *Signal detection theory* | | | | | | |
| Discrimination Sensitivity ($A'$) | 0.72 (0.17) | 0.58 (0.22) | 0.03 | 0.48 (0.07) | 0.47 (0.07) | 0.61 |
| Response bias ($B''$) | −0.05 (0.09) | 0.08 (0.51) | 0.22 | 0.27 (0.13) | 0.17 (0.10) | 0.08 |

Note: Standard deviations are in parentheses. RAT = Remote associate test.

ITEM and WARNING, $F(1, 74) = 11.0$, $p = 0.001$, $\eta_2 = 0.09$, indicating that a warning moderated participants' monitoring ability to distinguish the list item from the critical lure. Planned comparisons showed that the effect of ITEM (i.e. a monitoring ability) was significant in the warned group, $t(39) = 5.35$, $p < 0.001$, but not in the unwarned group, $t(37) = 0.87$, $p = 0.39$, confirming that a warning significantly facilitates the ability to discriminate list items from critical lures. As expected, the ITEM x WARNING interaction was further qualified by a three-way interaction with AFFECT, $F(1, 74) = 4.84$, $p = 0.03$, $\eta_2 = 0.04$. This three-way interaction between ITEM, WARNING, and AFFECT was further analyzed by separate two-way ANOVAs and planned comparisons, as discussed below.

We pursued the three-way interaction by WARNING. In the warned group, the main effect of ITEM was significant, $F(1, 38) = 29.7$, $p < 0.001$, and significantly interacted with AFFECT, $F(1, 38) = 4.13$, $p = 0.04$, $\eta_2 = 0.05$, suggesting that AFFECT modulated monitoring abilities to tell list items from critical lures. Planned comparisons showed a significant difference between true recognition (for the list item) and false recognition (for the critical lure) in both affect conditions, but this effect was more pronounced in the positive-affect condition, $t(20) = 5.59$, $p < 0.001$, Cohen's $d = 2.03$, than in the neutral-affect condition, $t(18) = 2.29$, $p = 0.034$, Cohen's $d = 0.74$; note that the effect size of the former is approximately three times greater than that of the latter. Moreover, when the two affect groups were compared with respect to true and false recognition, we found no difference in true recognition, $p = 0.55$, but a significant group difference in false recognition, with substantially less false recognition in the positive-affect condition ($M = 42.5$) than in the neutralaffect condition ($M = 56.5$), $t(38) = −2.315$, $p = 0.026$, Cohen's $d = −0.72$. This suggests that the interaction between ITEM and AFFECT was driven by substantially reduced false recognition (i.e. recognition for the critical lure) in the positive-affect condition compared to the control condition – and, in turn, that the positive-affect group, compared to the control, apparently paid more attention to – or took greater advantage of – the warning instruction, which resulted in better discrimination between the presented list item and the nonpresented critical item (Gallo et al., 2001; McCabe & Smith, 2002). In the unwarned group, however, neither the main effect of ITEM nor the ITEM x AFFECT interaction was significant, $p = 0.23$, and $p = 0.51$, respectively, suggesting that true and false recognition were comparable, regardless of induced affect; participants in both affect groups were not able to discriminate the list item from the critical lure. Consistent with the literature, our planned comparisons showed that the two affect groups differed neither in true recognition, $p = 0.13$, nor in false recognition, $p = 0.79$.

Finally, to examine a linear trend of reduction in false recognition across the groups, we conducted a linear contrast analysis in an ANOVA model, with a weight of 0 assigned to the two unwarned groups (positive, neutral) as a combined control group. A weight of −1 was assigned to the warned-positive group, and a weight of 1 to the warned-neutral group. The result of this contrast test was significant, $F(2, 75) = 2.35$, $p = 0.02$, $\eta_2 = 0.07$, indicating a significant linear trend for reduced false memory across the groups, with the greatest reduction in the warned positive-affect group, followed by the warned neutral-affect group and, lastly, by the unwarned groups. This suggests that when a warning was given, the positive-affect group, compared to the other groups, apparently benefited the most from the warning, which is believed to promote monitoring or decision processes that diminish false memory (Figure 1).

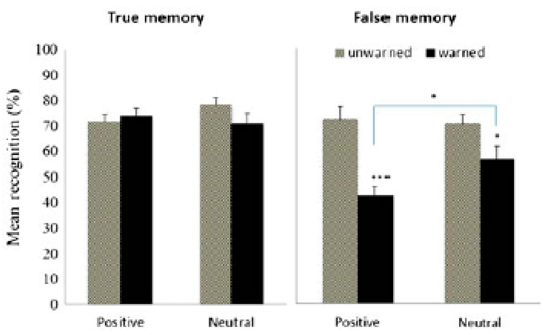


Figure 1. True memory (for the list item) and false memory (for the critical lure) are shown as a function of induced affect (positive vs. neutral) and warning instructions (warned vs. unwarned). Standard errors of the mean are presented in T-bars.

### *Signal detection analysis*

Given our finding that the positive-affect group, which was warned, showed a significantly lower level of false recognition than the neutral-control group, we used signal detection theory to examine whether their recognition memory had been influenced by either discrimination sensitivity (A′) or response bias (B″). A′ scores ranged from 0 to 1, where 0 indicates poor discrimination between presented words and non-presented critical words and 1 represents perfect discrimination. The B″ score indicates whether an individual displayed a response bias when making a recognition decision. A negative B″ score reflects conservative criteria (likely to say no), while a positive score reflects a liberal bias (likely to say yes). Independent-samples t-tests revealed significant group differences for sensitivity (A′), $t(38) = 2.17$, $p = 0.03$ suggesting that the positive-affect group in the warned condition was better able to discriminate list items from their associated critical lures than were their counterparts in the same warned condition (see Table 1). This may suggest further that the happy people in the warned group resorted to more rigorous monitoring. In terms of their response bias (B″), however, the two affect groups did not differ, $t(38) = -0.124$, $p = 0.22$. Further analysis showed that the two affect groups in the unwarned condition did not differ in either discrimination sensitivity or response bias. This suggests that our finding – that individuals who experienced both positive affect and warning had the lowest false recognition – can be explained by an enhanced ability to discriminate list items from critical lures (i.e. monitoring ability), but not by an overall criterion shift in the positive-affect condition.

## General discussion

Our findings suggest that, with enhanced monitoring due to warning, positive affect reduces false memory. Given the literature that has demonstrated that such a reduction in false memory through warning can be attributed to monitoring processes during the encoding phase (for a review, see Gallo et al., 2001; McCabe & Smith, 2002), the most parsimonious explanation is that positive affect enhances participants' capability to monitor encoding processes. Our findings can also be explained in alternative ways.

First, item-specific processing – which involves encoding items by their distinctive perceptual features (Hege & Dodson, 2004) – can also play an important role in the reduction of false recognition. Given that a prior warning also entails item-specific processing (McCabe, Presmanes, Robertson, & Smith, 2004), it is possible that enhanced item-specific processing in a positive affect state can contribute to monitoring. Some might disagree that positive affect can facilitate item-specific processing even in the absence of perceptually distinctive features such as pictorial cues (Arndt & Reder, 2003; Schacter, Israel, & Racine, 1999). The literature, however, suggests that reduced false memory by item-specific processing can also be achieved using non-perceptual attributes (Hunt, 1995; Hunt & McDaniel, 1993; McCabe et al., 2004). For example, McCabe et al. (2004) have demonstrated that a manipulation of encoding instructions can lead to item-specific reductions in false memories without perceptually distinctive features. It is plausible, therefore, that because they had been warned about intrusion effects, our positive-affect group may have engaged in item-specific processing by actively generating unique cues to rehearse presented list items distinctively, which could result in a rejection of non-presented critical lures. In addition, it can be argued that if the positive-affect group had engaged in item-specific encoding for presented items, true recognition should have been enhanced (which we did not find) because individual list items were encoded distinctively. The literature, however, suggests that the true-recognition measure in most DRM experiments is not a very sensitive measure of item-specific processing because enhanced true recognition can occur not only by item-specific processing but also by relational processing (Hunt, 1993; McCabe et al., 2004). Storbeck and Clore (2005, 2011) have also demonstrated that item-specific processing – which was observed in the negative-affect condition – reduced false recognition in the DRM paradigm, but did not affect true recognition. Taken together, it is important to note that in a positive affect state, item-specific processing can potentially be used concurrently with monitoring processes to reduce false memories (McCabe et al., 2004).

Second, it is plausible that a set of higher order cognitive processes that are believed to underlie monitoring abilities can also attenuate false memory. For instance, recent studies have documented that attentional control or working memory capacity influence one's susceptibility to false memory in the DRM paradigm primarily because of improved source monitoring (Leding, 2012; Figure 1. True memory (for the list item) and false memory (for the critical lure) are shown as a function of induced affect (positive vs. neutral) and warning instructions (warned vs. unwarned). Standard errors of the mean are presented in T-bars.  Peters et al., 2008). Therefore, it is also possible that either enhanced attentional control or working memory capacity – both of which are shown to improve in a positive-affect state (Carpenter et al., 2013; Yang et al., 2013) – contribute to monitoring abilities that in turn help suppress false memories. Similarly, it is possible that positive affect's facilitating effect on cognitive flexibility (Isen, 2008) – an ability to spontaneously restructure one's knowledge in myriad ways – may cause a reduction in false recognition, especially when the warning encourages the participant to carefully attend to the specific relation between list items and critical items. For instance, Libby and Neisser (2001) have demonstrated that an awareness of the structural knowledge of the specific relation between list items and critical items in the DRM list reduces false memory by placing constraints on the way gist-based information is used during a memory test. Given that cognitive flexibility implicates the increased control of attention (e.g. Yang et al., 2013), it is possible that improved cognitive flexibility under positive affect has contributed to a reduction in false memory. Further investigation that aims to disentangle the influence of attentional control (or working memory capacity) from that of monitoring processing will have a potential to shed light on mechanisms underlying the role of positive affect in facilitating the effect of a warning.

Together, our study contributes to the literature by demonstrating that even short-lived positive affect confers beneficial consequences on false memory, especially when vigilant monitoring is encouraged by warning. This finding is notable, in that individual differences in emotionality can regulate false memory as assessed by the DRM paradigm.

### *False-memory theories*

False-memory theories that take a dual-process approach explain our findings rather neatly and provide a useful basis for interpreting the theoretical implications. First, the activation-monitoring framework contends that the critical lure is automatically activated, but subsequent monitoring processes can prevent its encoding resulting in a reduction in false memory (Gallo et al., 2001; Roediger et al., 2001). Along these lines, our findings suggest that with enhanced vigilance through warning, positive affect reduces false memory by exerting differential influences on various memorial processes. Second, the fuzzy-trace theory posits that two independent gistbased or verbatim-based representations are associated with different types of encodings: (a) relational encoding based on semantic processing or (b) item-specific encoding based on perceptual distinctiveness (Brainerd, Wright, Reyna, & Payne, 2002). The fuzzy-trace theory suggests that although positive affect increases the general tendency to encode DRM lists in terms of gist-based information, its reliance on verbatim-based information may facilitate item-specific processing and cause a reduction in false memory. Thus, in light of the fuzzy-trace theory, our results indicate that positive affect does not always increase false recognition – even if it facilitates gist-based or relational encoding – because of the possibility that positive affect could influence verbatim- based processes such as monitoring, item-specific encoding, or other attention-based controlling processes, either at encoding or retrieval.

### *Theories on the effect of positive affect on cognitive processes*

Several theories have been proposed to account for the effect of positive emotion on cognitive performance. The first of these, the dopamine hypothesis, posits that positive affect should improve higher order cognitive processes, such as working memory or controlled attention because it is associated with the release of dopamine into brain areas, such as the prefrontal cortex and anterior cingulate, that are believed to contribute to high-order cognitive processes such as error monitoring (Dehaene, Posner, & Tucker, 1994) or strategic memory search (Rosen & Engle, 1997). Given that these higher order processes may serve as cognitive resources to promote monitoring processes, our results are compatible with the dopamine hypothesis (see Ashby et al., 1999). Second, Fredrickson's broaden-and-build theory (2001) holds that positive emotions broaden our momentary thought–action repertoires and build on enduring personal resources. The broaden-and-build theory, therefore, is also compatible with our findings, because positive affect would invoke adaptive actions and intellectual resources (e.g. executive control), especially when the warning allows participants to actively adapt to the needs of task situations.

While our findings provide evidence in favor of these theoretical assertions, they cannot be readily explained by the third theory, the AAI theory, which contends that positive affect signals that the immediate environment is safe, and therefore heuristic and effortless processing ensues instead of detail-oriented systematic processing (e.g. Schwarz & Clore, 1983). It is notable, however, that Bless et al. (1996) argue that positive affect decreases neither cognitive capacity nor processing motivation in general. Specifically, in Bless et al.'s Experiment 2, the positive-affect group – despite having had more false memories than the negative-affect group – performed better on an unrelated secondary task than both the neutral and negative groups. In view of this, our findings can be reconciled with those of Bless et al.'s, in that although participants in the positive condition relied on less taxing gist-based encoding (i.e. general knowledge) to remember the DRM words, they were at the same time able to take advantage of available resources to monitor for the non-presented critical lures. Moreover, in light of the AAI model, a warning could have posed a problem in the environment, and therefore participants handled the DRM task by adopting more systematic and detail-oriented processing rather than heuristic processing. Specifically, it is possible that the warning may have actually caused the participants in the positive-affect condition to not use gist-based information and, instead, employ more systematic or item-specific encoding or a more controlled memory strategy.[2] In turn, this heightened attention to item-specific details could have led to better performance.

### *Limitations and future studies*

First, since we did not induce neutral affect in the neutral- affect condition (i.e. the non-induction condition), it is arguable whether our neutral-affect condition actually experienced neutral affect. Given that affective states can be characterized by major attributes, including valence (positive, neutral, negative) and arousal (high, low), our evidence suggests that participants in the neutral-affect condition experienced less specific and less intense affect than those in the positive-affect condition (Isen, 2008). For example, in terms of valence, the RAT score (used as an index of experienced pleasantness) suggests that participants in the control condition felt less pleasant than those in the positive-affect condition. Our funnel questionnaire also consistently indicated that the neutral-affect group felt less pleasant ($M = 5.05$) than their counterparts ($M = 6.02$). Moreover, in terms of self-reported arousal, the funnel questionnaire showed that the two affect conditions did not differ. Taken together, this suggests that the non-induction condition differed from the positive-affect condition in terms of the experienced valence (i.e. degree of pleasantness), but not in terms of arousal, which renders it an adequate comparison group for examining the effect of positive affect.

In addition, it is worth noting whether our affect-induction method induced specific positive emotions (e.g. gratitude) rather than general positive affect. Despite the possibility that the gift paradigm could have induced more specific positive emotion, it is notable that our affect-induction method (i.e. a small bag of hard candies) was designed to induce mildly positive affect, in particular, for the following two reasons. First, given the paltry value of the gift, participants may have felt a fleeting emotion (i.e. gratitude) that lasted only a few seconds. Specifically, since the participant was asked to put the gift away with their other belongings before the start of the study, it is plausible that the participant could have been distracted from a sense of gratitude, which is generally triggered by receiving something considered to be costly to provide, valuable, or altruistically offered (Wood, Froh, & Geraghty, 2010). Second, we tried to minimize potential demand characteristics by ensuring that the participant would not eat the candy and associate it, during the session, with the purpose of the study. When we examined items on the funnel questionnaire that were included to gage participants' awareness of the research hypotheses and suspicions about the study, we found no evidence that participants had linked the gift to any part of the study. Moreover, the same protocol, which had been used in other studies (Yang et al., 2013; Yang & Yang, 2014), was found to be effective in minimizing demand characteristics. It is less likely, therefore, that participants – at least, in our study – felt specific emotions (e.g. gratitude or contentment) as a result of the gift they received at the start of the study and tried to perform better.

Although it is beyond the scope of this work, it is also debatable whether specific positive emotions (e.g. gratitude, contentment, or amusement) would be equally able to enhance the effect of a warning on false memory in the DRM paradigm. Notwithstanding the differential effects of those specific emotions that can be considered positive (but not positive-affect states), mild positive-affect states induced by various kinds of inductions have often been found to produce the same behavioral effects (for a review, see Isen, 2008). That is, the literature suggests that regardless of the specific underlying emotion, mildly positive affect that is low in arousal and motivational approach likely exerts similar effects. In view of this, although the unexpected-gift paradigm we employed could have induced either gratitude or contentment, their effects would be similar – rather than dissimilar – to our current findings if such emotional states are low in both arousal and motivational approach (Gable & Harmon-Jones, 2008). We acknowledge, however, that overgeneralizing this observed effect to other general positive emotions with varying intensity and arousal should be avoided.

Fourth, given the literature that suggests that negative affect is not simply the inverse of positive affect, but rather a separate entity (Watson & Tellegen, 1985), our conclusion that positive affect facilitates the effect of a warning on false memory should not be interpreted to suggest that negative affect would have either similar or differential effects on false memory. In addition, although our funnel questionnaire suggests that it was positive affect – not arousal – that facilitated the effect of a warning, we acknowledge the possibility that the participant's self-reported arousal, as assessed at the end of the study, was not necessarily the same throughout the study. Therefore, future studies should consider not only negative affect or varied positive emotions (e.g. gratitude or contentment), but also a potentially intricate interaction between affective states and arousal level over time.

Another caveat is that our findings may be less conclusive regarding whether the effect of positive affect and warning is due to encoding or retrieval, as our study was not designed for this purpose. We speculate, however, that since our warning instructions encouraged the participant to engage in vigilant monitoring, especially right from the start of the study period, the effect of positive affect and a warning could have been stronger during encoding than retrieval. Consistent with this, Storbeck and Clore (2005, 2011) also suggest that affective states (e.g. sadness) influence false memory through encoding processes and not retrieval processes. Further study is warranted, however, to clearly disentangle the specific memory process underlying the effect of positive affect and warning on false memory, specifically by independently manipulating the timing of affect induction and warning instructions.

Finally, it is not certain whether our findings can be generalized to other forms of episodic false memories evidenced by a range of research paradigms. For instance, some researchers claim that the DRM paradigm is of little relevance to episodic false memory (Freyd & Gleaves, 1996), while others suggest a potential link. For example, women with posttraumatic stress disorder after childhood sexual abuse or those who report repressed memories have shown increased rates of false memories in the DRM paradigm (Bremner, Shobe, & Kihlstrom, 2000; Clancy, Schacter, McNally, & Pitman, 2000). Although these studies suggest that there may be a link between DRM phenomena and repressed memory, we acknowledge that generalizing our findings to a more general episodic type of false memory (i.e. eyewitness memory or suggestibility) should be undertaken with caution – especially since episodic memory often requires access to the context of and personal participation in an event, thereby implicating more complicated memory processes than the phenomenon of false memory assessed in the DRM paradigm (see Wheeler, Stuss, & Tulving, 1997). Further studies, therefore, are needed to establish such generalizability.

## Concluding remarks

Our most significant finding is that in the DRM paradigm, when the condition includes a warning, positive affect reduces false memory by actively engaging in monitoring (or item-specific) processes to regulate automatic activation of related critical lures. This finding is notable in that individual differences in emotionality can regulate false memory, as assessed by the DRM paradigm. Although more research is needed to understand the mechanisms that underlie the relationship between false memory and positive affect, our study provides important practical implications, particularly for educational and clinical practices. Specifically, given that learning semantically related concepts or information requires the ability to deal with substantial interference, our findings suggest that positive affect may provide useful cognitive resources to better deal with such interference while facilitating efficient and accurate learning. Moreover, given that therapeutic interventions often elicit false memories, inducing positive affect and warning patients before they undergo such interventions might reduce their susceptibility to false memories.

Our study provides theoretical insight into previous studies in which the effect of positive affect on false memory was examined without considering its impact on monitoring aspects (e.g. Bless et al., 1996; Storbeck & Clore, 2005). In contrast, our findings demonstrate that the inclusion of a warning profoundly influences the impact of positive affect on false memory, changing how cognitive resources are used in support of cognitive activity. Given the significance of this finding for resolving competing positions in the literature, future studies should attempt to replicate it in other false-memory paradigms (e.g. the memory-implantation paradigm). Future research will also be needed to more fully explain the specific cognitive processing (i.e. item-specific processing or monitoring) or memory strategies through which positive affect operates to suppress the occurrence of false memories.

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## Notes

1. We acknowledge that a greater reliance on general knowledge structures may not necessarily be harmful, as it does not always entail strict reliance on rigid schemas. It is notable, however, that the effectiveness of general knowledge structures should be determined by whether these structures are pertinent to the primary task. Namely, if general knowledge structures directly relate to the primary task, such reliance would render the primary task less taxing and more rewarding (Bless & Fiedler, 2006). For instance, in terms of creativity, general knowledge structures can be beneficial or harmful. If the creativity task requires either fluency or flexibility – which are promoted by an associative mode that is useful for considering multiple domains – greater reliance on general knowledge structures can be beneficial (for a review, see Wiley & Jarosz, 2012). In contrast, if the creativity task demands innovation or originality – which are achieved by suppressing either routinized or schema-based modes – extensive reliance on general knowledge structures can be undesirable, because it may result in mental fixedness, cognitive

anchoring, or heightened focus on a particular domain-specific knowledge, all of which would adversely affect creative performance.

2. We thank the anonymous reviewer for suggesting this possibility.

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