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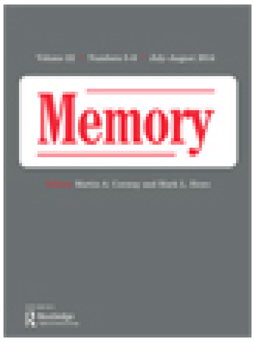

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Undermining belief in false memories leads to less efficient problem-solving behaviour

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ABSTRACT

Memories of events for which the belief in the occurrence of those events is undermined, but recollection is retained, are called nonbelieved memories (NBMs). The present experiments examined the effects of NBMs on subsequent problem-solving behaviour. In Experiment 1, we challenged participants' beliefs in their memories and examined whether NBMs affected subsequent solution rates on insight-based problems. True and false memories were elicited using the Deese/Roediger–McDermott (DRM) paradigm. Then participants' belief in true and false memories was challenged by telling them the item had not been presented. We found that when the challenge led to undermining belief in false memories, fewer problems were solved than when belief was not challenged. In Experiment 2, a similar procedure was used except that some participants solved the problems one week rather than immediately after the feedback. Again, our results showed that undermining belief in false memories resulted in lower problem solution rates. These findings suggest that for false memories, belief is an important agent in whether memories serve as effective primes for immediate and delayed problem-solving.

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Nonbelieved memory; belief; recollection; false memory; problem-solving

Jack has a memory in which he put his hand in a cage at the Philadelphia Zoo and his left wrist was bitten by a monkey. Years later, his mother assured him that it never happened. He does not believe the horrible event actually happened, but he cannot stop having vivid "recollections" or "memories" concerning the event (http://www.falsememoryarchive.com/). The question is, when Jack comes across monkeys in the zoo, will he stay away from them?

Memories of events for which the belief in the occurrence of those events has been undermined, but the recollection has been preserved, are called nonbelieved memories (NBMs). This recently studied phenomenon turns out not to be rare, with more than 20% of people reporting that they have vivid but nonbelieved autobiographical memories (Mazzoni, Scoboria, & Harvey, 2010). A lingering question is whether these NBMs have any impact on behaviour (e.g., avoiding monkeys). The current experiments delve into this question by examining the (in)dependent behavioural consequences of beliefs and recollections on performance on subsequent problem-solving tasks.

Previous research on the behavioural consequences of memories has predominantly focused on *believed* memories (Scoboria et al., 2014), with few studies looking at the behavioural consequences of NBMs. An important reason why we focus on the behavioural consequences of NBMs is that there is a new line of research that has demonstrated that belief and recollection are independent constructs that can have differential effects on behaviour (Scoboria, Mazzoni, Kirsch, & Relyea, 2004; Scoboria, Talarico, & Pascal, 2015). Here, *belief* refers to the truth value related to the occurrence of an event, whether or not a recollection is present. *Recollection* refers to the mental re-experiencing of an event (e.g., Rubin, 2006). Various theorists argue that memories contain key components that lead to both a sense of re-experiencing the event and a belief that the event actually occurred (e.g., Brewer, 1996; James, 1890/1950; Schacter, 1996; Tulving, 1985).

In recent years, this view has gained more attention, with the distinction between belief and recollection being supported by empirical research. For example, Scoboria et al. (2014) used structural equation modelling and found that factors that predicted recollection (e.g., perception, re-experiencing) were distinct from factors that predicted belief (e.g., plausibility), suggesting a dissociation between recollection and belief. For most of our memories, belief and recollection both contribute to remembering. Scoboria and Talarico (2013) found that for believed autobiographical memories, belief and recollection ratings both tend to be at the high end (above 7) on a 1–8 Likert scale.

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However, in other cases, only belief or recollection is present. For example, there are family stories (e.g., your birth) that one believes occurred but cannot recollect. There are also NBMs where vivid recollections of events exist (e.g., believing you actually saw Santa Claus putting presents under the tree as a child) but beliefs for these events are undermined (e.g., by acquiring knowledge that Santa Claus is a fictional character) (Mazzoni et al., 2010; Otgaar, Scoboria, & Mazzoni, 2014).

An examination of NBMs may help uncover how belief and recollection interactively lead to behavioural outcomes. For instance, in studies investigating how believed memories impact behaviour, participants exhibited superior public-speaking performance and higher levels of exercise if believed memories of relevant positive experiences were activated (see Biondolillo & Pillemer, 2015; Pezdek & Salim, 2011). However, because these "memories" were both believed and recollected, it is hard to know whether it was recollection, belief, or both that were responsible for the changes in subsequent behaviour.

Research concerning false memories has also examined the impact of belief on behaviour. For example, Bernstein and Loftus (2009) reviewed a number of studies where researchers created false memories about childhood events, such as being ill after eating egg-salad. These memories resulted in a subsequent reduction in eating egg-salad. Again, however, it is hard to determine the source of change in subsequent behaviour as belief and recollection were confounded. That is, participants developed a false belief about the false memory (event) with approximately a quarter of participants reporting having recollections of the false event (also see, Scoboria, Mazzoni, Jarry, & Bernstein, 2012). Indeed, these authors were acutely aware of this problem as Laney, Morris, Bernstein, Wakefield, and Loftus (2008, p. 291) noted that,

> the data in the present paper represent some false memories and some false beliefs. But because it is awkward to say 'false memories and false beliefs' repeatedly, we generally just use one term (either "false memory" or "false belief") to encompass the notion of planting a false entity.

To our knowledge, there is no research that has directly and experimentally tested whether it is false belief or false recollection that affects behaviour (but see Otgaar, Moldoveanu, Wang, & Howe, 2016). Recently, Bernstein, Scoboria, and Arnold (2015) conducted a mega-analysis on previously published food-preference experiments (see above) and concluded that for false events, belief is more important than memory in modifying food preference. Indeed, they stated that, "[c]ompared to memory of past events, belief in the occurrence of past events is more important for altering attitudes and behaviors" (p. 6). However, in all the experiments reviewed, belief and recollection for the suggested false events were neither intentionally nor clearly manipulated separately. Moreover, NBMs were not addressed in any of the experiments. Perhaps more importantly, food preferences may result in part from decision-making processes that are analytic and occur consciously. For instance, participants might reason: "Since egg-salad made me ill, I'd better not eat it." However, in a problem-solving process that involves intuitive thinking or "Aha!" experiences (e.g., insight-based problem-solving; Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Howe, Garner, Dewhurst, & Ball, 2010), there is usually no explicit reasoning about facts/knowledge. Recollection might play a vital role independent of belief in insight-based problem-solving behaviour where people are unaware of the processes underlying the solutions to these types of problems.

The current experiments

The main purpose of the current experiments is to examine the impact of NBMs on insight-based problem-solving behaviour. We decided not to use the food preference paradigm to elicit false beliefs/memories because this paradigm only allows one false belief or false memory to be created per participant. Because so few false beliefs and memories are created, it is even more difficult to produce the necessary number of NBMs. Therefore, we opted for a method that leads to high and reliable levels of false memories, the Deese/Roediger–McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In this paradigm, participants are presented with lists of associated words (e.g., *butter*, *food*, *eat*, *sandwich*) that are all related to a non-presented critical lure (i.e., *bread*). Participants not only correctly remember (recall, recognise) items presented on the lists but also form false memories for critical lures that were not presented. In the present experiments, after false memories were formed with the DRM paradigm, participants were challenged on their responses by telling them certain items were not presented in an attempt to create nonbelieved false memories. Data from our lab (Otgaar et al., 2016) have confirmed that nonbelieved false memories can be created using the DRM paradigm. Also by using this paradigm, we were able to examine the impact of beliefs on true memory and explore the effects of nonbelieved true memories on behaviour.

Following the challenges to true and false memories, participants were asked to solve compound remote associate task (CRAT) problems, in which solutions referred to nonbelieved and believed words (true and false memories from DRM lists). A CRAT problem consists of three words (e.g., *Board/Mail/Magic*). To solve the problem, participants have to come up with a word that could link all the three words (in the example given above, the answer was *Black*). Howe et al. (2010) presented participants with DRM lists and then asked participants to solve CRAT problems whose solutions were critical lures for the DRM lists. They found that CRAT problems primed by false memories for critical lures were solved more frequently and significantly faster than problems that were not primed. Subsequent research typically showed the priming effect of believed false memories on CRAT problems (Howe, Garner, Charlesworth, & Knott, 2011; Howe, Wilkinson, Garner, & Ball, 2016); and found that the priming effect of false memories was similar to or even stronger than that observed for true memories (Howe, Threadgold, Norbury, Garner, & Ball, 2013; Howe, Wilkinson, Monaghan, Ball, & Garner, 2013). Based on Bernstein et al.'s work (2015), we predicted that if belief is more influential than recollection when it comes to impacting subsequent behaviours that ostensibly require non-conscious problem-solving processes, no priming effect would be found after beliefs for false memories are withdrawn. However, if recollection plays a more vital role in priming the CRATs than beliefs, then nonbelieved false memories should prime as many CRATs as believed false memories.

We were also interested in exploring individual differences in the formation of NBMs. Social feedback has been found to be one of the main contributors to fostering NBMs (Scoboria, Boucher, & Mazzoni, 2015) and hence we included the Gudjonsson Compliance Scale (Gudjonsson, 1989) in order to examine individual differences in social compliance. Furthermore, a scale measuring dissociative symptoms was administered because dissociation has frequently been linked to the formation of false memories (Giesbrecht, Lynn, Lilienfeld, & Merckelbach, 2008).

Experiment 1

Method

Participants

Before the recruitment of participants, we ran a power analysis using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007), with an estimated power of 0.80 and a medium effect size of 0.25 (f). The power analysis revealed that 34 participants needed to be tested. A total of 36 students from Maastricht University participated in the experiment in exchange for credit points or a financial reward of €7.50. Two participants were excluded because they did not complete the CRAT problem-solving session, thus leaving 34 participants (14 males and 20 females). All participants were native English speakers, aged between 17 and 34 ($M_{age} = 21.6$, $SD = 3.26$). The experiment was approved by the ethical committee of the Faculty of Psychology and Neuroscience, Maastricht University.

Materials

DRM lists. Sixteen DRM lists were used in our experiment. These lists have successfully been used in previous research (e.g., Howe, Garner, & Patel, 2013). Each DRM list included 12 associated words (e.g., *butter*, *food*, *eat*, *sandwich*) and these words are all related to a non-presented target or "critical lure" (i.e., *bread*). Importantly, to eliminate possible item effects arising from differences between a studied item and a critical lure, for eight lists the first list word was replaced by the critical lure (see also Howe et al., 2013). Thus, these "critical lures" are no longer "false" memories as they now become "true" studied items presented as part of the list. The other eight lists were standard DRM lists that had the corresponding eight critical lures. The recognition task contained 56 words, of which 24 items were presented items from the DRM lists, 8 were non-presented critical lures from the DRM lists, and 24 words were not presented and served as unrelated lures.

CRAT problems. We used 24 CRAT problems in this experiment (taken from Howe et al., 2013). Each CRAT was composed of three words (e.g., *crust*, *stale, French*), all of which could be solved by a single linking word (i.e., *bread*). Sixteen CRATs were primed by the preceding 16 DRM lists: half of the CRAT problems were primed by lists whose false memories (critical lures) were the solution words and the other half were primed by lists whose true memories (studied items) were the solution words (see Appendix). The other eight CRATs were not primed and served as an unprimed control condition. The mean solution rate and solution time for each CRAT were known from previous research (Howe et al., 2013). Figure 1 illustrates the alignment of DRM items and CRAT problems.

Gudjonsson Compliance Scale (*GCS*; Gudjonsson, 1989). The GCS is a self-report questionnaire measuring the degree of compliance. It contains 20 true/false statements (e.g., "I often give in to people when I am under pressure"). The total score of GCS ranges from 0 to 20, with higher scores indicating more compliant tendencies. The CGS has an internal consistency of 0.71 and a test–retest reliability coefficient of 0.88.

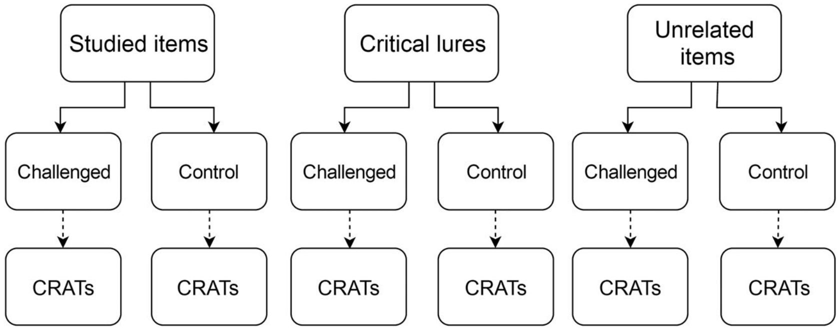

Figure 1. Diagram of alignment between DRM items and CRAT problems.

Dissociative Experiences Scale (*DES*; Bernstein & Putnam, 1986). The DES measures the degree to which people experience dissociative symptoms. It consists of 28 items (e.g., "Some people find that sometimes they are listening to someone talk and they suddenly realize that they did not hear part or all of what was said.") and participants have to select what percentage of time this happens to them from 0% to 100% with 10% increments. It has a good internal consistency, with Cronbach's $\alpha = .92$.

Design and procedure

A 3 (memory type: critical lures, studied items, unrelated items) × 2 (belief: challenged vs. control) within-subject design was used. Participants were tested individually for approximately 50 minutes in lab facilities at the faculty. There were four phases.

(1) *Study phase:* DRM words were presented to participants on a computer screen. Participants were instructed to remember as many words as they could. Each word was visually presented for 1500 ms, with 500 ms interstimulus interval using the program Visual Basic. The sequence of the words within a list was fixed, but the order of the lists was randomised.

(2) *Recognition phase:* After a distractor task (playing the game Bejeweled for 3 min), participants were involved in a recognition task, in which 8 critical lures, 24 studied words, and 24 unrelated words were included to examine false memories and true memories. Participants were asked to identify the word on the screen as to whether it had been presented by clicking on a "Yes" or "No" button. Next, participants completed the dissociation questionnaire (DES) before they moved to the challenging phase (see below).

(3) *Challenging phase:* Participants were told that the computer graded their answers and gave them feedback on their performance on the previous recognition test. Before their responses were challenged, participants were told why our memories were sometimes unreliable and they were shown an extra DRM list to illustrate how a DRM list could lead to the formation of false memories. This explanation was given so participants understood why feedback was presented.

In the challenged belief condition, when a certain target word (e.g., *bread*) appeared on the screen, a label beneath the word popped up stating that "Sorry, your previous answer was incorrect. This word was not presented." In the control condition, the feedback was "Congratulations, your answer was correct. This word was presented." In this way, we attempted to create nonbelieved and believed memories. When the feedback was provided, the experimenter showed participants a printed fake proof where presented words were listed and gave oral social feedback asking them to rethink their previous answer. Then immediately after the challenge for each word, participants rated their memory and belief for that word on 1–8 Likert scales (i.e., "Do you have a memory for this word?", 1 = no memory at all, 8 = clear and complete memory; "Do you believe that this word was presented to you?", 1 = definitely did not happen, 8 = definitely did happen; adapted from Scoboria et al., 2004). The experimenter explained thoroughly to the participant the difference between memory (i.e., recollection) and belief. The sequence of all challenged words was randomised. In total, 56 words from the recognition test were given feedback, but we were only interested in the 24 target words that served as solutions to the corresponding CRAT problems. The belief in half of the target words (4 critical lures, 4 studied words, and 4 unrelated) was always challenged regardless of their original recognition responses. The other words were in the control condition in which participants' belief in their presence was not challenged.

(4) *Problem-solving phase:* Twenty-four CRAT problems were presented in which the correct answers were the target words in the challenging phase. The 24 CRATs were assigned to six (3 × 2) conditions. An ANOVA revealed no statistically significant differences between mean solution rates across different item types ($F(2, 18) = 0.01$; $p = .99$) and different belief conditions ($F(1, 18) = 0.001$; $p = .97$). There were no solution time differences across item types ($F(2, 18) = 0.02$; $p = .98$) and belief conditions ($F(1, 18) = 0.16$; $p = .70$). These analyses were done as a manipulation check to make sure that there was no baseline difference in reaction times and solution rates among clusters of CRATs across conditions.

Participants were falsely told that the problem-solving phase was a separate experiment aimed at examining how personality (i.e., the dissociation questionnaire) affected problem-solving style. Participants were instructed that three words would be presented on the screen and their task was to come up with a word that could link all the three words. Participants were given an example first (e.g., the answer to the problem *apple/family/house* was *tree*), followed by one practice CRAT problem that they had completed themselves before they began the test CRATs. Problems were presented in a random order. A countdown timer appeared in the upper right corner of the screen and participants were asked to type their solution within 60 seconds. Upon completion of each CRAT, no correct answer was given to lower the risk that participants would connect the memory task with the problem-solving task. Solution rates and times were recorded by the computer. After all sessions, participants filled in the compliance scale (GCS) and were debriefed about the purpose of the study.

Results and discussion

Recognition rates

The mean recognition rate for all studied items was 74.50% ($N = 608$). The mean false recognition rate for critical lures was 69.13% ($N = 188$), which is consistent with previous research (e.g., Blair, Lenton, & Hastie, 2002). Participants

Table 1. Recognition rates in different memory type and belief conditions (*M*, 95%CI).

	Memory type		
	Critical lures	Studied items	Unrelated items
Challenged belief	0.68 [0.57, 0.80]	0.88 [0.82, 0.93]	0.10 [0.06, 0.15]
Control condition	0.70 [0.60, 0.80]	0.85 [0.77, 0.92]	0.19 [0.11, 0.27]

falsely recognised 14.63% ($N = 20$) of non-presented unrelated items.

The mean recognition rate in each condition is shown in Table 1. Recognition rates were analysed using a 3 (memory type: critical lures, studied items, unrelated items) × 2 (belief: challenged vs. control) repeated measures ANOVA. No interaction was found, $F(2, 66) = 1.57$, $p = .22$, partial $\eta^2 = .05$. There was a main effect of memory type, $F(2, 66) = 185.51$, $p < .001$, partial $\eta^2 = .85$, where Bonferroni's *post hoc* analyses showed that participants recognised statistically more critical lures and studied words than non-presented words ($ps < .001$). There was no main effect of belief, $F(1, 33) = 0.91$, $p = .35$, partial $\eta^2 = .03$, indicating that there were an equivalent number of true and false memories in both the challenged belief and control conditions.

Nonbelieved and believed memories

We recorded memory and belief ratings for each word after the challenge manipulation. Analogous to previous research, we employed the following criteria for NBMs: recollection needed to be rated at least 2 scale points higher than belief (see Mazzoni, Clark, & Nash, 2014; Otgaar et al., 2016), and within this criterion, the recollection rating should be at least 3. For believed memories, we set the same criterion for recollection rating (at least 3) as in NBMs, and belief rating should be equal to, or above, 3. Within the categories of nonbelieved and believed memories, if the item was a critical lure, it was a false memory; if it was a studied item, it was a true memory. For unrelated items, there were two categories: items with no belief and no memory (ratings ≤2) and items with no memory but belief. Table 2 shows the mean memory and belief ratings for words in each condition.

After the challenge manipulation, 97.1% of the participants ($n = 33$) had formed at least one nonbelieved true memory for studied items, with an average number of 3.15 (SD = 1.05) NBMs. In all, 79.4% of the participants ($n = 27$) had developed at least one nonbelieved false memory, with an average number of 2.24 (SD = 1.52). In the challenged belief condition, participants formed nonbelieved false memories for 55.88% of the critical lures and formed nonbelieved true memories for 78.68% of the studied words. In the control condition, participants formed believed false memories for 91.18% of the critical items and formed believed true memories for 89.71% of the studied words.

Solution rates of CRATs

The mean CRAT solution rates (in proportions) were calculated for each participant. We focused on words that were effectively manipulated into believed/NBMs. We labelled the effect of successfully challenging or lowering participants' beliefs as "undermining". Seven participants had formed either zero nonbelieved false memories or zero nonbelieved true memories; hence, the CRAT solution rates of these cases were treated as missing values. However, these participants had CRAT solution values in the believed memory conditions, thus we used a multiple imputation method (Schafer, 1997) to impute missing data values. In total, 3.9% of the data (8 out of 204 cells) were imputed over 5 cycles of imputations. We compared the CRAT solution rates in the undermining belief condition with the CRAT solution rate in the control condition for the following three memory types: critical lures, studied items, and unrelated items.[1] Interestingly, undermining belief led to different results for false and true memories.

Table 2. Mean memory and belief ratings in each kind of induced memory (CI: confidence interval; *n*: number of participants contributing to the mean score; *N*: number of items contributing to the mean score).

	Memory rating (95% CI)	Belief rating (95%CI)	Memory-belief
Nonbelieved false memory	5.02 [4.61, 5.44] ($n = 27$; $N = 76$)	1.42 [1.12, 1.71] ($n = 27$; $N = 76$)	3.60
Nonbelieved true memory	5.75 [5.33, 6.17] ($n = 33$; $N = 107$)	1.96 [1.64, 2.28] ($n = 33$; $N = 107$)	3.79
No belief no memory	1.27 [1.13, 1.40] ($n = 33$; $N = 121$)	1.23 [1.09, 1.38] ($n = 33$; $N = 121$)	0.04
Believed false memory	6.46 [5.97, 6.94] ($n = 34$; $N = 124$)	7.25 [6.92, 7.59] ($n = 34$; $N = 124$)	−0.79
Believed true memory	7.09 [6.81, 7.36] ($n = 34$; $N = 122$)	7.59 [7.41, 7.78] ($n = 34$; $N = 122$)	−0.50
Belief with no Memory	1.94 [1.62, 2.26] ($n = 30$; $N = 93$)	6.36 [5.85, 6.86] ($n = 30$; $N = 93$)	−4.42

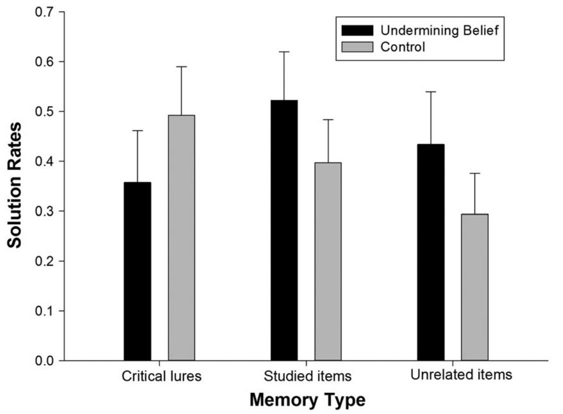

Figure 2. Mean solution rates in different memory type and belief conditions (Experiment 1). Error bars indicate 95% confidence intervals.

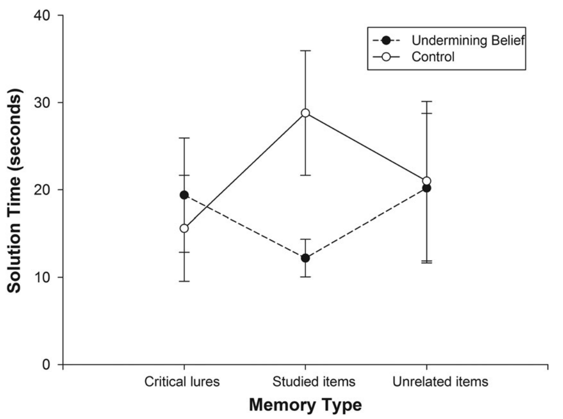

Figure 3. Mean solution times in different memory type and belief conditions (Experiment 1). Error bars indicate 95% confidence intervals.

In the critical lures condition, undermining belief ($M = 0.36$, SD = 0.29) led to statistically lower solution rates than control ($M = 0.49$, SD = 0.28), $t = -2.04$, $df_{pooled} = 884$, $p = .04$. However, for studied items, undermining belief increased solution rates significantly (undermining belief, $M = 0.52$, SD = 0.27; control condition, $M = 0.40$, SD = 0.25, $t = 2.04$, $df_{pooled} = 3353$, $p = .04$; see Figure 2). We compared the CRAT solution rates in the control condition to see whether the results in the control condition were consistent with previous research. Paired samples t-tests showed that false memories did not differ significantly from true memories in priming the CRATs ($p = .27$); false and true memories both primed more CRATs than unrelated items ($p = .008$; $p = .02$). Thus, the results in the control condition replicate previous findings on the consequences of false memories on problem-solving (e.g., Howe et al., 2013).

As has been done in previous related work (e.g., Otgaar et al., 2015), we also performed an additional analysis by focusing only on the items that participants recognised as "presented" in the recognition test. When words with "yes (presented)" recognition responses only were included in analysis, a similar interaction effect between memory and belief was found, $F(2, 64) = 5.36$, $p < .01$, partial $\eta^2 = .14$. No main effect of belief was found, $F(1, 32) = 0.35$, $p = .56$. No main effect of memory was found, $F(2, 64) = 2.37$, $p = .10$.

Solution times of CRATs

Mean solution times of CRATs (in seconds) in each condition were calculated. We were particularly interested in comparing the solution times between nonbelieved and believed memories. In some cases, participants solved no CRATs under the priming of (non)believed memories, thus solution times in that condition were counted as missing. In total, there were 19.11% ($N = 39$) of the cases where solution times were missing. We conducted several paired sample t-tests and again found decreasing belief had different effects for false and true memories (Figure 3). In the critical lures condition, nonbelieved false memory ($M = 17.75$, SD = 9.07) primed problems as fast as believed false memory ($M = 14.47$, SD = 7.16; $p = .27$); however, in the studied items condition, undermining belief ($M = 12.80$, SD = 5.18) resulted in faster solution

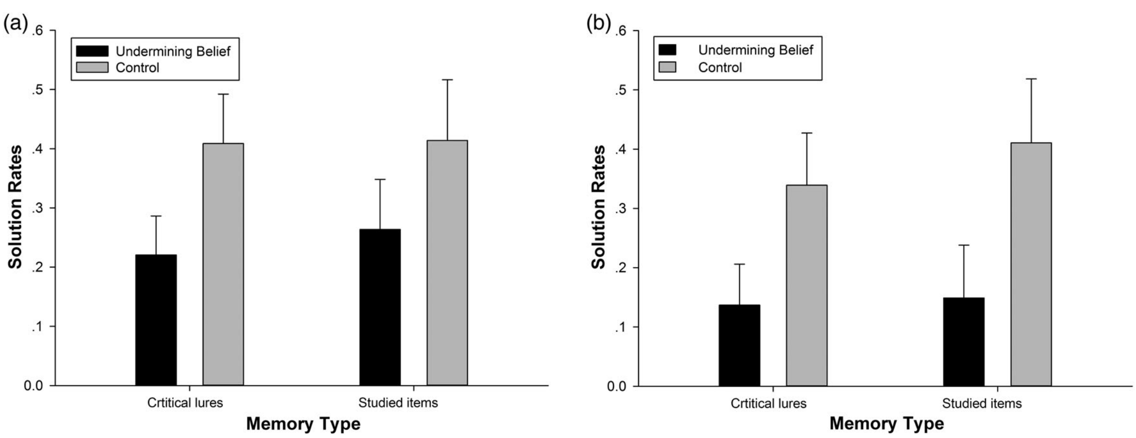

Figure 4. (a) illustrates solution rates primed by different memory types and belief conditions in the immediate group (Experiment 2). (b) illustrates results in the one-week delay group. Error bars indicate 95% confidence intervals.

times to CRAT problems than in the control condition (M = 20.33, SD = 10.30; p = .003). Undermining belief (M = 15.33, SD = 9.58) and control conditions (M = 18.28, SD = 12.15) did not differ in solution times for unrelated items (p = .77).[2]

Exploratory analysis

We conducted Pearson's correlations between the scores on the GCS and the different memories (believed true/false memory; nonbelieved true/false memory). We found a statistically significant correlation between GCS scores and false recognition rates (r (32) = .38, p = .03): the higher scores on the GCS, the higher false recognition rates. No correlation between GCS scores and true recognition rates was detected. As GCS scores measure compliance, we expected that the more compliance participants exhibited, the more NBMs they would report. However, no statistically significant correlation was found between GCS scores and the number of nonbelieved false memories (r (32) = .31, p = .07).

Correlations between DES scores and different kinds of memories were also analysed. We found a statistically significant negative correlation between dissociative symptoms and true recognition rates (r (32) = −.44, p = .01). Thus, participants scoring high on dissociation had worse memories for presented words. No correlation was found between DES scores and false recognition rates. Interestingly, dissociation scores correlated negatively with the number of nonbelieved unrelated items (r (32) = −.36, p = .04) but not nonbelieved true memories (r (32) = −.08, p = .64) or nonbelieved false memories (r (32) = −.01, p = .94). Of course, we had a small sample size for executing correlation analyses, so the results of these analyses should be cautiously treated.

Experiment 1 examined the behavioural consequences of belief and recollection. We found that in the control condition, false memories primed the CRATs as efficiently as true memories, a finding consistent with previous research (Howe et al., 2010). Interestingly and for the first time, our data also showed that, without belief, the priming effect of false memories was changed under the conditions tested. This is in line with research by Bernstein et al. (2015). That is, when belief in false memories was withdrawn, participants solved fewer CRAT problems. This result constitutes the first experimental attempt that shows that nonbelieved (false) memories impact problem-solving behaviour and do so differently than true memories.

Some might argue that believed false memories primed more CRATs than nonbelieved false memories because a higher number of believed false memories were created. However, our data on the other memory types did not support this idea. In the studied item condition, there were more believed true memories induced, but believed true memories did not prime more CRAT problems than nonbelieved true memories. Others might argue that memory for an event is different from memory for a word and the implication of studying NBMs for words might not be so illuminating. Indeed, an event consists of multiple elements and usually a recollection of an event contains more vivid details than a recollection of a word. Hence, NBMs for events might exhibit greater behavioural impact than NBMs for words.

Although our data suggest that for false memory, belief might play an active role in problem-solving, our study is still preliminary and needs replication. Furthermore, the results of this experiment were somewhat limited because of the following. First, in this experiment, there were only four CRATs in each condition. When we attempted to induce NBMs for the four solution words to these CRATs, not all of the items could be successfully transformed into NBMs. The average nonbelieved memory rate of critical lures and studied items was in the 55–80% range. If there are more items in each condition, more NBMs can be created and thus, the effects of beliefs and recollections can be better investigated. Second, the CRAT problems in each condition were fixed; that is, they were not completely randomised for every participant. Although the mean solution rates and times for CRATs were counterbalanced across conditions, it is unknown whether the difficulty of CRATs impacted our results. In order to address these issues and thus, replicate our results, we conducted an additional experiment.

In Experiment 2, we assigned more CRAT problems to each condition and CRAT problems were no longer fixed in each condition. Furthermore, having established the immediate effect of undermining belief on problem-solving, Experiment 2 explored the long-lasting effects of NBMs on problem-solving behaviour. From a theoretical perspective, this is important because previous studies have found that the superior priming effect of false memories emerged particularly after a one-week delay while the priming effect of true memories declined (Howe et al., 2013). One possible explanation is that true memories decay faster than false memories because true memories are often *other-generated* (e.g., presented on a list by the experimenter), whereas false memories tend to be *self-generated* [i.e., occurring spontaneously and automatically as a result of internal semantic activation (Howe, Garner, Threadgold, & Ball, 2015)]. This pattern corresponds to findings from previous studies on false memories and food preferences in which the behavioural impact of belief could last for months (Bernstein & Loftus, 2009). Furthermore, previous research has shown that false beliefs can last up to four months (see Geraerts et al., 2008; Laney, Fowler, Nelson, Bernstein, & Loftus, 2008) and experimentally evoked nonbelieved false memories endure for as long as a month (Otgaar, Scoboria, & Smeets, 2013).

Because the behavioural effects of false beliefs may be long-lasting and because belief is more easily manipulated than memory, one could anticipate the following. If belief is the more active agent in guiding behaviour than memory, then undermining belief should lead to behavioural effects even after a delay. As belief is assumed to be part of knowledge related to the self (e.g., Scoboria et al., 2004), the enduring behavioural effects of belief would be especially evident for false memories as they are the result of internal associative activation and thus, self-generated. Hence, in Experiment 2, half of the participants had to complete the CRAT problem-solving task immediately and the other half following a one-week delay.

Experiment 2

Method

Participants

A power analysis indicated that 70 participants were needed when a power of 0.80 and a medium effect size of 0.27 (f) were estimated. A total of 71 participants were tested in exchange for credit points or a financial reward of €7.50. The sample consisted of 22 males and 49 females, with a mean age of 22.3 years old (SD = 5.97). 84.5% of the participants ($n = 60$) were native English speakers, and 15.5% ($n = 11$) of the participants were fluent in English, but used English as a second language.

Materials

Twenty-four DRM lists were used in Experiment 2. Each list contained 10 associates. The recognition phase included 12 non-presented critical lures from 12 of the DRM lists, 48 studied items (in which 12 were targeted items for belief manipulation), and 36 unrelated items. Twenty-four CRATs whose answers were 12 critical lures and 12 studied items (corresponding to the 24 DRM lists) were used. The GCS and DES questionnaires were administered to participants as well (see Experiment 1).

Design and procedure

A 2 (time interval: immediate vs. 1 week) × 2 (memory type: critical lures vs. studied items) × 2 (belief: challenged vs. control) mixed design was used, where the first factor was between-subjects and the other two were within-subject factors. Thirty-six participants were randomly allocated to the immediate condition and 35 to the one-week delay condition. Experiment 2 followed the same procedure as Experiment 1, except that 35 of the participants did not finish the problem-solving phase immediately after the challenging phase, but instead, did so one week later. Because the items in the challenged belief and control belief conditions were fixed, we switched the items in these two conditions for half of the participants in each time interval group. That is, belief for the same 12 target words was undermined in around half of the participants ($n = 31$), but belief for these words was not challenged in the other participants.

Table 3. Mean recognition rates for critical lures and studied items in different conditions (N: number of recognised items).

		Critical lures	Studied items
Immediate	Challenged belief	69.0% ($N = 149$)	85.6% ($N = 185$)
	Control condition	68.5% ($N = 148$)	81.5% ($N = 176$)
One-week delay	Challenged belief	58.6% ($N = 123$)	81.4% ($N = 171$)
	Control condition	62.9% ($N = 132$)	76.2% ($N = 160$)

Results and discussion

Recognition rates

The mean recognition rate for unrelated items was 14.5%. For the targeted studied items and critical lures (i.e., those that served as the solutions to the subsequent 24 CRATs), the mean recognition rates in each condition are shown in Table 3.

Nonbelieved and believed memories

Memory and belief ratings for each word were recorded after the belief manipulation for that word. The same criteria for nonbelieved and believed memories used in Experiment 1 were used here. Table 4 shows the mean percentages of critical lures and studied items that were nonbelieved and believed memories.

Solution rates of CRATs

Again, we labelled the effect of successfully challenging or lowering participants' beliefs as "undermining". A 2 (time interval: immediate vs. 1 week) × 2 (memory type: critical lures vs. studied items) × 2 (belief: undermining vs. control) repeated measures ANOVA was conducted, with time interval as a between-subjects variable. Note that there were 14 participants in total who did not form a nonbelieved true or a nonbelieved false memory. These participants' CRAT data were not entered into the analysis. As a result, 34 participants were in the immediate condition and 23 were in the delay condition. There was no statistically significant three-way interaction effect for time interval × memory type × belief, $F(1, 55) = 0.14$, $p = .71$, and also no statistically significant two-way interactions. There was a main effect for belief, $F(1, 55) = 20.68$, $p < .001$, partial $\eta^2 = .27$, which, like Experiment 1, showed that undermining belief resulted in lower solution rates. There was no

Table 4. Percentages of critical lures and studied items that were nonbelieved and believed memories in each condition.

		Critical lures	Studied items
Immediate	Challenged belief (nonbelieved memories)	58.33% ($N = 126$)	61.17% ($N = 132$)
	Control condition (believed memories)	91.67% ($N = 198$)	95.33% ($N = 206$)
One-week delay	Challenged belief (nonbelieved memories)	45.23% ($N = 95$)	48.09% ($N = 101$)
	Control condition (believed memories)	84.28% ($N = 177$)	87.62% ($N = 184$)

main effect for memory type, $F(1, 55) = 1.37$, $p = .25$, partial $\eta^2 = .02$. Neither was there a main effect for time interval, $F(1, 55) = 0.44$, $p = .51$, partial $\eta^2 = .008$ (Figure 4).

The above analysis is based on using the filtering criterion of NBMs having memory ratings that were at least two points higher than belief ratings. When we adopted the criterion of memory ratings being at least three points higher than belief ratings, a statistically significant main effect of belief was detected as well, $F(1, 55) = 44.10$, $p < .001$, partial $\eta^2 = .45$. As in Experiment 1, we performed an additional analysis by focusing on the items that participants recognised as "presented" in the recognition test. Even when only the recognition responses with "Yes (presented)" were included, a statistically significant main effect of belief was found, $F(1, 67) = 18.70$, $p < .001$, partial $\eta^2 = .21$, showing that undermining belief led to less efficient problem-solving behaviour. No main effect of memory type was found, $F(1, 67) = 1.25$, $p = .26$. There was no significant main effect of time interval, $F(1, 67) = 0.003$, $p = .96$ and no statistically significant interactions were detected.[3]

To rule out the possibility that the effect of belief was due to the difficulty of the CRATs, we changed the CRAT problems in the undermining belief and control conditions in around half (45.1%, $n = 32$) of the participants. We split the data into two groups in which participants received the opposite belief manipulation for the same materials. For instance, in one group, belief for "bread" was undermined and then participants solved a corresponding CRAT; in the other group, belief for "bread" was confirmed and participants solved the same CRAT. We conducted a 2 (change: yes vs. no) × 2 (memory type: critical lures vs. studied items) × 2 (belief: undermining vs. control) repeated measures ANOVA, with change as a between-subject variable. No significant main effect of change was found, $F(1, 55) = 2.44$, $p = .12$, indicating that the materials did not impact our results.

Solution times of CRATs

We were also interested in whether undermining belief would impact CRAT solution times. For critical items, we conducted a 2 (time interval: immediate vs. one-week delay) × 2 (belief: undermining vs. control) repeated measures ANOVA, with the first variable being between-subjects. Like Experiment 1, when participants solved no CRAT under the priming of (non)believed memories, no solution time data in that condition could be analysed. There were 37 participants' solution time data that could be used. There was no main effect of belief, $F(1, 36) = 0.45$, $p = .51$, time interval, $F(1, 36) = 0.28$, $p = .60$, or interaction effect, $F(1, 36) = 1.34$, $p = .25$. For studied items, we conducted the same analysis. We found no main effects of time interval or belief. Thus, CRAT solution times for false and true memories were not impacted by belief and time interval.

Exploratory analysis

We found no statistically significant correlation between compliance scores and the number of NBMs (r (69) = .04, $p = .73$), which is consistent with Experiment 1. The data from both experiments suggest that compliance does not impact the formation of NBMs. Correlations between dissociative symptoms and the number of true/false believed and NBMs were analysed. We found no significant correlation between dissociative symptoms and true recognition rates (r (69) = −.21, $p = .08$), and also no significant correlation between dissociation and false recognition rate (r (69) = −.20, $p = .09$) emerged. No correlation was found between DES scores and the overall number of NBMs (r (69) = .07, $p = .59$).

Consistent with Experiment 1, we found that undermining belief in false memories led to fewer CRAT problems being solved than the control condition. Belief is conceptualised as the truth value of an event. Even though a CRAT is an insight-based problem-solving task, retracting belief in false memories impacts the ability of false memories to prime CRATs. The results on false memories from Experiment 1 and Experiment 2 align with Bernstein et al.'s (2015) conclusion that false autobiographical beliefs, not memories, alter behavioural performance.

What we also found was that undermining belief in true memories resulted in lower CRAT solution rates. In Experiment 1, we did not find this. The reason might be that we made several improvements in Experiment 2, such as including more CRATs in each condition, and assigning the CRATs to each condition in a more balanced way. In addition, in Experiment 2 we found no statistically significant results on CRAT solution times. The main reason for this might be that there was limited data on the solution times for CRATs. Only when participants solved at least one CRAT problem could we obtain solution time data. This can be resolved in future studies by using easier CRAT problems. Also, our results showed that the deleterious effects of belief retraction on problem-solving occurred both immediately and after one week. This shows that when belief is undermined, it does not have a short-lived effect, but it endures over time. This is line with research by Otgaar et al. (2013) who showed that NBMs can last for a month.

General discussion

The current experiments serve as the first attempt to simultaneously assess the behavioural consequences of non-believed and believed memories on problem-solving behaviour. We found evidence across two experiments that NBMs impacted problem-solving behaviour under the conditions tested. The most intriguing finding was that undermining belief in false memories led to less efficient problem-solving behaviour. This result persisted even after a one-week delay. To our knowledge, this is the first experimental demonstration that for false memories, retracting belief adversely affects subsequent behaviour.

This novel finding implies that belief contributed more to the behavioural performance on the CRATs than recollection. This is in line with previous research suggesting belief in the occurrence of past events was more important in determining eating behaviour than recollection (Bernstein et al., 2015). However, in this work, no experimental test was performed to manipulate belief separately and examine whether this would impact behaviour. Our study is the first showing the consequences of belief and recollection on behaviour by using a non-inferential, and perhaps more automatic, insight-based problem-solving task.

Our findings have several theoretical implications. The data on NBMs support the distinction between belief and recollection. The distinction between belief and recollection was not made in the memory literature until recently (e.g., Mazzoni & Kirsch, 2002; Otgaar et al., 2015; Scoboria et al., 2004; Scoboria et al., 2014). Previous studies mostly showed dissociation of belief and recollection for autobiographical events. For instance, research has shown that belief in actions (e.g., clapping hands) could be undermined while the recollected aspect of the actions remained intact (Clark, Nash, Fincham, & Mazzoni, 2012; Mazzoni et al., 2014). Also, experiments showed that belief in experiencing a hot balloon ride can be manipulated while recollection of the event remained intact (Otgaar et al., 2013). In our two experiments, we undermined belief for associatively related words and recorded belief and memory ratings afterwards. We found that for both false and true memories, belief ratings dropped while memory/recollection ratings were high after undermining belief.

Scoboria et al. (2014) proposed a theoretical model to explain the relationship between belief and memory (recollection). In this model, autobiographical belief and recollection are two independent continuous dimensions that result in different categories such as believed memories and NBMs. Our experiments support this view inasmuch as we successfully manipulated participants' beliefs while recollections were retained. Based on the independence of these two components, it is proposed that belief in the occurrence of an event, rather than a specific memory for the event, is highly malleable and is the critical component in influencing behaviour (Bernstein et al., 2015; Scoboria et al., 2014). Importantly, we found that for false memories, undermining belief led to a reduction in subsequent problem-solving behaviour, a finding that accords well with the above proposition. As belief in occurrence is based in various inputs, just one of which is recollection, theories that focus on episodic recollection alone may not be the best predictors of behaviour.

In Experiment 2, we found evidence that for true memory as well, problem-solving was more difficult when belief was undermined. This suggests that for memory in general, behaviour is predominantly influenced by believing the event rather than recollecting the event. It is unclear why we did not find this effect in Experiment 1. Although one might expect that challenging true memories is more difficult than false memories (e.g., Otgaar, Candel, Smeets, & Merckelbach, 2010), this is not what we found in the present experiments. Here, both nonbelieved true and false memories were evoked, something that might be related to the fact that the DRM procedure leads both to high levels of true and false recognition, with false recognition rates often not differing from true recognition rates (Roediger & McDermott, 1995). Of course, future research should examine more closely whether belief is also important in guiding behaviour for true memory.

Associative-activation theory (AAT, Howe, Wimmer, Gagnon, & Plumpton, 2009; Otgaar, Howe, Peters, Smeets, & Moritz, 2014) as well as the activation-monitoring theory (Roediger, Balota, & Watson, 2001) provide explanations for the priming effects of false memories. AAT suggests that processing of one concept activates a corresponding node and this activation spreads automatically to nearby associative concept nodes. When DRM list items are presented and encoded, their activation spreads to non-presented, but related items (i.e., the critical lure) resulting in false memories. Because false memories are highly associated with true memories, they often exert a similar priming effect on CRAT problems (Howe et al., 2013). In our experiments, we manipulated participants' beliefs for the items after false and true memories were formed, and we found a similar reduced priming effect for both true and false memories (Experiment 2). One possibility might be that undermining belief adversely affects spreading activation in one's knowledge base, thereby reducing its effects on subsequent tasks including the spreading activation required to solve CRATs. Of course, further investigation is needed to examine the precise mechanism by which belief and recollection can impact problem-solving behaviour.

One might argue that the manipulation of belief in our experiments might have changed the automatic nature of the priming process. In Experiment 2, the data showed that the CRAT solution rates primed by true memories still remained high even after a one-week interval, but previous research has found that these rates dropped after a one-week delay (Howe et al., 2013). Priming CRATs in prior research is considered to occur automatically by associative activation (Howe et al., 2010). Querying belief (e.g., undermining) in the current experiments may have made the recollections of true and false items more conscious and salient, which may have fundamentally changed the priming process. However, if we look at the data of the control condition in the immediate testing group, we found the exact same result with previous studies (solution rates: critical lures ≥ studied items > unrelated items), and in the immediate group, belief was also queried in the control condition. This suggests that our belief manipulation might not have affected the automatic nature of our priming effects.

Our study also explored the relationship between compliance and NBMs. Both experiments demonstrated no statistical link between compliance scores and the number of NBMs. Scoboria, Boucher, et al. (2015) found that the primary reason people retracted their belief in a memory was social feedback, such as someone telling you that your memory was not true. Our study found that people who were more compliant did not form more NBMs than people who were less compliant. One reason for this is that social feedback is more related to external pressure, such as suggestive information, whereas compliance can be regarded as an internal personality characteristic. Our null result begs the question whether the formation of NBMs might be more affected by external factors such as who provides social feedback (e.g., authority or stranger).

One might object that our memory task is related to the problem-solving task and that this is a potential confound in our experiments. However, in food preference studies (Bernstein & Loftus, 2009), participants created false beliefs or memories towards a negative food experience in the first session, and then the amount of that food they ate was measured in the second session. Participants' eating behaviour was measured weeks or months after the first session (e.g., Geraerts et al., 2008; Scoboria et al., 2012). They were told that the second session was a completely irrelevant experiment as to reduce the chance that participants could link the two sessions with each other. Importantly, in the current experiments, we also told participants that our problem-solving task was an unrelated task. By way of confirmation that our manipulation succeeded, we interviewed some participants after the experiments and none of them could see the link between the memory task and the problem-solving task.

To conclude, our experiments provide the first evidence that for false memories, problem-solving was hampered when belief was reduced. This shows that belief is the most active agent in impacting problem-solving behaviour. Indeed, our experiments reveal novel evidence that belief and recollection have distinct behavioural consequences. The time has now come to extend this finding and investigate whether such differential consequences might also appear in other situations.

Notes

1. In this analysis, words were evaluated as NBMs when memory ratings for them were two points higher than belief ratings. When we adopted a stricter criterion (i.e. memory ratings were at least three points higher than belief ratings), we found a same interactive pattern and the true memory effect was less pronounced (see supplementary document).
2. The pattern of results was basically similar when a three-point criterion (i.e. memory recollection was rated at least three points higher than belief) for NBMs was adopted.
3. We examined whether being native English speaker or not would impact the results. When non-native English speakers were excluded, there were 29 participants in the immediate group and 17 participants in the delay group and the result pattern was not changed by the exclusion.

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Appendix. Examples of DRM lists and CRAT problems

Critical lures	Black	Bread	Car	Needle	Fruit	Shirt
	white	butter	truck	thread	apple	Blouse
	dark	Food	bus	pin	vegetable	sleeves
	charred	Eat	automobile	eye	orange	pants
	night	sandwich	vehicle	sewing	kiwi	tie
	funeral	Rye	drive	sharp	citrus	button
	colour	Jam	jeep	point	ripe	shorts
	grief	Milk	Ford	prick	pear	iron
	death	flour	keys	thimble	banana	polo
	ink	Jelly	garage	haystack	berry	collar
	coal	dough	highway	thorn	cherry	vest
	brown	crust	van	injection	basket	pocket
	grey	Slice	taxi	syringe	juice	jersey
Associated CRAT	Board/mail/magic	Crust/stale/french	Chase/police/toy	Knitting/pine/work	Salad/bowl/juice	Football/flannel/vest