Putting false memories into context: The effects of odour contexts on correct and false recall

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RUNNING HEAD: Context and false memory

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Abstract

False memories created by the Deese/Roediger-McDermott (DRM) paradigm are often accompanied by contextual information. Yet, research investigating the effects of context on false memories is surprisingly scarce. We used the context-dependent memory (CDM) model to construct same versus different context conditions using odours as contexts and DRM lists as to-be-remembered stimuli. Experiment 1 showed that levels of correct recall were higher in the same-context condition than in the changed-context condition, but no effects of context were observed in false recall. Experiment 2 used different odours and a longer retention interval and showed that context dependent memory effects were found for both true and false memory. For true memory, context reinstatement improved memory, whilst simultaneously reducing false memory. Theoretical and forensic implications of these findings are discussed.

Keywords: False memory; context-dependent memory; DRM paradigm

Putting False Memories into Context: The Effects of Odour Contexts on Correct and False Recall

In the past several decades, two memory phenomena have received more attention than most: false memory and context-dependent memory. Research bridging these topics is, however, surprisingly scarce. Research into false memories increased after Roediger and McDermott (1995) revived a procedure originally developed by Deese (1959). In this procedure, presenting lists of words (e.g., *bed*, *dream*, *wake*, etc) that are associates of a non-presented 'critical lure' (in this case, *sleep*) produces a memory illusion whereby the critical lures are falsely recalled or recognized. The Deese/Roediger-McDermott (DRM) paradigm is now one of the mostly widely used methodologies in memory research (see Gallo, 2010, for a review). Studies of the effects of environmental context on memory have consistently shown that memory performance is greater when the encoding context is reinstated at retrieval (see Smith & Vela, 2001, for a review). Yet, despite widespread interest in false memories and context-dependent memory, we have found no documented studies directly investigating the connection between these two memory phenomena. The current study represents a first step in addressing this gap in the memory literature.

The absence of prior research into the effects of context on false memories is particularly surprising given that false memories produced by the DRM paradigm are often reported with contextual information. Contextual details that have been attributed to falsely remembered words include their colour and location at study (Lyle & Johnson, 2006), modality of presentation (Gallo, McDermott, Percer, & Roediger, 2001), and characteristics of the speaker such as their gender (Payne, Elie, Blackwell, and Neuschatz , 1996) and voice (Lampinen, Neuschatz, & Payne, 1999; Roediger, McDermott, Pisoni, & Gallo, 2004). Lyle and Johnson attributed such effects to errors of source monitoring whereby features of studied items are reactivated at test and misattributed to the critical lures. Along the same lines, Lampinen, Neuschatz, and Payne (1999) proposed a familiarity-plus-corroboration account whereby a critical lure presented at test feels familiar due to its association with studied items. Participants then search their memory for details that corroborate the familiarity of the critical lure. False memories occur when details of studied items are erroneously attributed to the lure.

While the studies cited above show that false memories can feature contextual details, there have been no previous studies investigating the functional effects of environmental context on false memory. The only study we are aware of that has investigated the effects of context more generally was reported by Goodwin (2013), who investigated the effects of reinstating encoding strategies at test on false recall in the DRM procedure. Across three experiments, participants studied DRM lists under either elaborative encoding conditions (generating a story or associations to study items) or rote rehearsal conditions (repeating the list items). At test, participants were instructed to engage the strategy they had used at encoding or the alternative strategy. Experiments 1 and 2 showed that elaborative encoding led to lower levels of false recall than rote rehearsal, with no significant effects of retrieval strategy and no encoding x retrieval interaction. In Experiment 3, however, levels of false recall were lower when participants engaged the same strategy at study and test, regardless of whether this was elaboration or rote rehearsal. Thus, reinstating context as determined by encoding strategy reduced false recall rates.

A problem with using encoding strategy as the context, however, is that is it difficult to find strategies that differ sufficiently to produce context effects but do not influence false recall rates (as evidenced in Experiments 1 and 2 reported by Goodwin, 2013). One way to avoid this confound is to use context manipulations that do not have systematic effects of levels of false recall. In the current study we investigated the effect of context on false memory by manipulating environmental context rather than encoding strategy. A number of previous studies have shown that memory performance is greater when the encoding and retrieval of information take place in the same environmental context, rather than in different contexts. Probably the best-known example is the classic study by Godden and Baddeley (1975) in which scuba divers studied lists of words while on land or underwater and then attempted to recall them in either the same or alternative context. Godden and Baddeley found that participants recalled more words when learning and testing took place in the same context, regardless of whether this was on land or underwater.

This pattern has been observed with a wide range of context manipulations and is commonly referred to as context-dependent memory (CDM). Smith (1985) extended the context effect to sounds by manipulating background music and white noise. Also using music as a context, Mead and Ball (2007) found that changing the key of Chopin's *Waltz in A Minor, Op. 34 No.2* from a major to minor key produced CDM effects. Aerobic exercise and resting states were used by Miles and Hardman (1998) to produce a CDM effect. Thompson, Williams, L'Esperance, and Cornelius (2001) observed CDM effects when participants watched a stress-inducing skydiving video, while Baker, Bezance, Zellaby, and Aggelton (2004) observed CDM when participants chewed spearmint gum. Jerabek and Standing (1992) found that contexts do not have to be physically reinstated in order to affect memory but can exert CDM effects when participants imagine themselves back in the encoding context (see also Smith, 1979). Of direct relevance to the current study is the finding by Parker, Ngu, and Cassaday (2001) that CDM effects can be observed using odours as contexts.

As evidenced by the wide-ranging reports of CDM manipulations, context is a broad term. It does not seem to matter whether the contexts are locations, odours, music, or physical/mental states. Instead, the essential factor is the reinstatement of the encoding context at retrieval. This, however, begs the question of exactly which contextual features are important. With the overwhelming amount of sensory information available from the environment, implicit cognitive mechanisms must regularly attenuate irrelevant information (Treisman, 1960). In regards to the reinstatement paradigm, peripheral context can be *overshadowed* or *outshined* by more relevant contextual information (Smith, 1988, 1994; Smith & Vela, 2001). Overshadowing occurs when participants focus on noncontextual information, such as inter-item associations, during study. If contextual information context is not encoded at study it will not act as an effective retrieval cue when reinstated at test. Outshining occurs when participants focus on noncontextual information at test, for example by using inter-item associations as retrieval cues.

The effects of overshadowing and outshining can explain the findings of Fernandez and Glenberg (1985) that, across eight experiments, room changes did not affect memory when the stimuli encouraged associative processing. As the DRM procedure relies on associative processing, Fenandez and Glenberg's findings suggest that DRM stimuli may be resistant to manipulations of context. Specifically, environmental factors such as room information are irrelevant to the study task (ie., remembering associated lists of words). Thus, the overshadowing hypothesis predicts environmental context may not be encoded if associations are made between to-be-remembered items (i.e., list-words from the study phase). In a similar vein, if semantic information acts as the most beneficial retrieval cue (e.g., "I remember all the words had something to do with sleep"), information such as environmental context will be irrelevant during the test. Thus, both the overshadowing and outshining hypotheses predict that environmental CDM may not be observed when using DRM stimuli. This may explain the scarcity of research combining these two procedures.

Despite these concerns, some studies have reported a CDM effect using associatively related stimuli. For example, Smith, Glenberg, and Bjork (1978) found an environmental CDM effect for categorized lists of words, both in terms of the number of categories recalled and the number of words recalled per category. Environmental CDM effects have also been observed in memory for prose (Jensen, Dibble, & Anderson, 1971). Nevertheless, an environmental context that is entirely extraneous can be easily ignored. Also, DRM lists direct attention toward inter-item associations, not context-item associations. The methodological challenge, therefore, is to direct attention toward an extrinsic context without disrupting the primary task of creating associations between list items. In general, an environmental context manipulation (e.g., room changes) may not be sufficient. On the other hand, an odour context would be harder to ignore and, consequently, less likely to be disregarded during study and test manipulations.

Odours produce powerful effects on memory and have been shown to act as effective contextual cues (see Herz & Engen, 1996, for a review). Herz (1997) argued that odours must be distinctive and contextually incongruent to produce robust environmental CDM effects. For example, pine odours can be mistaken as a cleaning product and simply disregarded. On the other hand, psychology laboratories do not tend to smell strongly of peppermint; therefore peppermint should be more effective in terms of eliciting CDM. To further explore this idea, Ball, Shoker, and Miles (2010) asked participants to rate odours for four properties: *pleasantness, arousal, familiarity,* and *distinctiveness*. Ball et al. found main effects for the unpleasantness and distinctiveness of odours as well as an interaction between the two. These findings suggest the two primary factors for odour CDM are unpleasantness and distinctiveness.

The present investigation aimed to accomplish two goals. The first was to test if a CDM effect can be observed in correct recall when DRM lists are used as the stimuli. If correct responses are higher in a same-context condition then we can conclude the inter-item semantic context constructed through the DRM procedure does not overshadow or outshine the environmental context. The second goal was to explore how manipulations of context will influence the production of false memories. According to Lyle and Johnson (2006), contextual details of studied items can be activated at test and misattributed to critical lures. One possible outcome, therefore, is that reinstating the study context at test will facilitate the retrieval of contextual details for both studied and nonstudied items, thereby increasing both correct and false recall. On the other hand, Cann and Ross (1989) found that changing the odour context between study and test reduced recognition accuracy by increasing false alarms. Although their stimuli were not designed to elicit high levels of false alarms, their findings suggest that false memories might show the opposite pattern to true memories and increase when the odour context changes between study and test.

Experiment 1

Method

Participants. The participants were 88 undergraduate students recruited from a British university. They were randomly assigned to a condition upon their arrival subject to the constraint that equal numbers were assigned to each condition.

Design and materials. The experiment was a 2 (study odour: cinnamon vs. rosemary) by 2 (test odour: cinnamon vs. rosemary) between-groups design. Four lists of 10 words each were taken from Stadler, Roediger, and McDermott (1999) and presented in order of backwards associative strength. The critical lures for the four lists were *doctor*, *sweet*, *smoke*, and *chair*.

Some words that are common to American participants were removed from the list, as they were considered inappropriate for British participants (e.g., *lawyer* was removed from the *doctor* list). The words were presented aloud by a male voice at a rate of approximately 2s per word. The words were presented on an audio cassette, which the participant controlled throughout the experiment.

The odours chosen for the experiment were cinnamon and rosemary. These odours were selected based on their general distinctiveness from each other and strength of aroma. The odours were emitted by a heated oil basin. A tea candle was used to heat the oil abstract in the basin and release the odour in the air. The candles were lit 30 minutes prior to the beginning of each experiment in order to ensure that the odour reached plateau by the time the experiment began. The ceramic basins would be refilled with oil every 30 minutes to ensure a consistency in strength of odour. All oils used in this experiment were purchased from Calmer Solutions Inc. and came from 100 % essential oil abstraction. Two rooms were designated for the experimental sessions. Though the rooms were only 15 meters apart each participant travelled to each room so that even in a same context condition the distraction of travel would remain constant. In order to isolate the effects of the odour context, the two laboratory rooms selected were nearly identical. Both rooms were approximately 4 meters by 2 meters and were very similar in decor. The only minor difference was one laboratory had a computer on the desk and the other had stacks of books on the desk. They were virtually identical in all other respects (e.g., small in size, plain walls, single window, one desk, and two chairs). Before the testing phase, participants would complete a mathematical task of single digit addition, subtraction, and multiplication problems. These mathematical problems were randomly arranged on a single sheet of paper. The test consisted of a one-sided page with simple instructions and blank lines for participants to write down their recall responses.

Procedure. Participants were tested individually in a small research cubicle. Upon arrival, participants received instructions for the entire experiment. Participants frequently commented on the presence of the odour, but were told it was a lingering smell from an earlier, unrelated experiment. They were told they would switch rooms between the study and test phase, but little emphasis was put on this room change. Participants were informed they would hear four lists of words and would later complete a free recall test. They were then instructed to begin the study phase by activating the tape recorder when they felt ready to begin. Lists began with a numerical indication (e.g., list 1, list 2, list 3, etc.) to divide the lists into their appropriate themes. At the conclusion of each list the participant heard the phrase "end of list."

At the conclusion of the study phase, participants followed the experimenter to the testing room. Though many participants commented on the odour in the study room, rarely did participants make any comments about the odour in the testing room. Therefore, it is assumed they accepted the rationale of an unrelated experiment sharing the laboratories. Before beginning the test phase, they were asked to complete as many mathematical problems as possible in two minutes. The total distraction time between study and test, including travel, instructions, discussion, and mathematical task, was five minutes. Participants were then given the response sheet and instructed to write down as many words from the study lists as they could remember. Participants were allowed as long as they needed to complete this testing phase, which typically lasted between five and seven minutes.

Results and discussion

Table 1 shows the mean levels of correct and false recall as a function of study and test contexts. Correct and false recall data were analysed in separate 2 (study odour: rosemary vs. cinnamon) x 2 (test odour: rosemary vs. cinnamon) between-groups ANOVAs with alpha set at .05. All pairwise comparisons were Bonferroni-corrected. The analysis of correct recall showed nonsignificant main effects of study odour, $F(1,84) = 1.644$, $MSe = .02$, $p = .203$, $\eta_p^2 = .02$, and test odour, $F(1,84) = 1.541$, $MSe = .02$, $p = .218$, $\eta_p^2 = .02$. There was, however, a significant interaction between study and test odours $F(1,84) = 4.57$, $MSe = .02$, $p = .036$, $\eta_p^2 = .05$. Pairwise comparisons showed that, when cinnamon was present at study, correct recall was higher when cinnamon was present again at test than when rosemary was present at test, $p = .02$. There was no significant effect of test odour when rosemary was present at study, $p = .53$. The analysis of false recall showed nonsignificant main effects of study odour, $F < 1$, and test odour, $F(1,84) = 1.74$, $MSe = .11$, $p = .19$, $\eta_p^2 = .02$, and a nonsignificant interaction, $F < 1$. Unrelated intrusions were very low and not subjected to statistical analysis.

The first objective of Experiment 1 was to test if DRM stimuli are affected by odour context changes. Consistent with previous research (see Herz & Engen, 1996), a CDM effect was observed for correct recall, suggesting that odour context information was integrated with the stimuli at encoding. As a result, the odour in same context conditions was an effective cue at retrieval. However, this effect was only observed when cinnamon was present at study. Reinstating the odour of rosemary did not influence correct recall. The second aim of Experiment 1 was to investigate whether context changes influence the production of false memories. A CDM effect was not, however, observed in false recall.

There are a number of potential explanations for the null effect of odour context in false recall. One is the use of a retention interval of less than ten minutes. This is important to note for two reasons. Firstly, environmental context changes are more likely to occur with a longer retention interval (see Smith & Vela, 2001, for a review). Specific to odour context changes, several studies have found more powerful CDM effects with longer retention intervals (e.g., Cann and Ross, 1989; Dalton, 1993; Schab, 1990). Secondly, DRM false memories have been found to increase over a 24-hour interval (McDermott, 1996). A longer retention interval should, therefore, increase false memories and enhance the effects of context reinstatement.

Another possible reason for the null effect in false recall was the choice of odours. In accordance with the findings of Ball et al., (2010), the intention was to use two smells that had similar origins (i.e., cooking), were considered distinctive, and differed in terms of pleasantness. However, participants in Experiment 1 complained of the unpleasant nature of both odours. This was to be expected of rosemary as it has a particularly pungent smell, but it was a surprising response to cinnamon which is used for candles and cleaning products and is typically considered a pleasant smell. Previous research has shown a linear negative relationship between odour intensity and pleasantness (see Moss, Miles, Elsley & Johnson, 2016), It is possible, therefore, that the cinnamon oil used in Experiment 1 produced an odour of an intensity that was considered unpleasant. These problems were addressed in Experiment 2, which incorporated a 24-hour retention interval and replaced cinnamon with lemon, which is typically judged to be a pleasant odour. We also increased the number of DRM lists from four to six in order to increase the opportunity for false recall.

Experiment 2

Method

Participants. One hundred and four undergraduate students were recruited, none of whom had taken part in Experiment 1. Sixty participants were recruited from a British university and 44 from a North American university. Data from both groups were collected by the first author. Participants were randomly assigned to conditions upon their arrival at the laboratory subject to the constraints that equal numbers were assigned to each condition and that the ratio of British to American participants was the same for each condition.

Design and materials. The experiment was a 2 (study odour: rosemary vs. lemon) by 2 (test odour: rosemary vs. lemon) between-participants design. Participants were presented with six DRM lists of 10 words each. The critical lures were *window, anger, chair, doctor, sleep,* and *smoke*. Study words were presented on a pre-recorded audiotape. Care was taken to recreate the same kind of rooms that were used in Experiment 1. The rooms were again small in size with plain walls, one desk, and two chairs. The recall test was a plain sheet of paper with instructions to report the words they could recall.

Procedure. All participants studied and were tested individually. Upon arrival to the laboratory, participants were randomly assigned to either a same (rosemary/rosemary or lemon/lemon) or different (rosemary/lemon or lemon/rosemary) context condition. After completing the consent form and reading the written instructions they were given verbal instructions about the study and test phases. They were told they would be presented with a list of words and then complete a recall test the following day at the same time. Therefore, if a participant began their study phase at 11am, they returned the next day for the test phase at 11am. This caused issue for only one participant who completed the testing phase 26 hours, instead of 24 hours, after the study phase.

To begin the study phase participants were instructed to activate the audio recording. Lists began with the same numerical indication (e.g., list 1, list 2, list 3, etc.) as described in Experiment 1 and the phrase “end of list” was presented at the conclusion of each list. Once they had listened to all the study words, participants were thanked and reminded to return the following day. Upon their return, participants were again given brief instructions about the recall test. They were then given a blank sheet of paper and asked to write down as many words as they could remember, in any order, but to avoid guessing. Participants were allowed five minutes for this test, although all completed the task in less than three minutes.

Results and discussion

Preliminary analyses showed no significant differences between the British and American participants in either correct recall, $t(102) = .18$, $p = .86$, or false recall, $t(102) = .65$, $p = .52$. The data were therefore collapsed across nationality groups. Table 2 shows the mean levels of correct and false recall as a function of study and test contexts. Correct and false recall data were analysed in separate 2 (study odour: rosemary vs. lemon) x 2 (test odour: rosemary vs. lemon) between-groups ANOVAs. Neither study odour nor test odour produced significant main effects on correct recall, both Fs<1. These null effects were qualified by a significant interaction between study and test odours, $F(1,100) = 43.31$, $MSe = 34.64$, $p < .001$, $\eta_p^2 = .30$. Pairwise comparisons showed that, when the study odour was rosemary, correct recall was significantly higher when the test odour was rosemary than when it was lemon, $p < .001$. Likewise, when the study odour was lemon, correct recall was significantly higher when the test odour was lemon then when it was rosemary, $p < .001$.

In the analysis of false recall, there was a significant main effect of study odour, $F(1,104) = 5.13$, $MSe = 2.85$, $p = .026$, $\eta_p^2 = .05$, whereby levels of false recall were higher when the study odour was rosemary compared to lemon. The main effect of test odour was not significant, F<1. There was also a significant interaction between study and test odours, $F(1,104) = 16.06$, $MSe = 2.85$, $p < .001$, $\eta_p^2 = .14$. Pairwise comparisons showed that, when the study odour was rosemary, false recall was significantly lower when the test odour was rosemary than when it was lemon, *p* =.004. When the study odour was lemon, false recall was significantly lower when the test odour was lemon than when it was rosemary, *p* =.008. Unrelated intrusions were again very low and not subjected to statistical analysis.

The results of Experiment 2 extend those of Experiment 1. Levels of correct recall were higher when the odour context at study was reinstated at test. This effect was observed with both rosemary and lemon. The novel finding from Experiment 2 is that levels of false recall were lower when the odour context at study was reinstated at test, and again this effect was observed with both rosemary and lemon. In sum, reinstating the study odour context at test increased the accuracy of recall by simultaneously increasing correct recall and reducing false recall.

General discussion

The current study explored the effects of context manipulations on correct and false memory in the DRM paradigm. Experiment 1 showed a CDM effect in correct recall, whereby correct recall was higher when the encoding context was reinstated at retrieval than when the context was changed, but no effect of context in false recall. Experiment 2 replicated the CDM effect observed in Experiment 1 with a 24-hour retention interval. The CDM effects in correct recall are consistent with previous findings that CDM can be observed with stimuli that are processed associatively rather than as individual items, such as categorized lists (Smith et al., 1978) and prose (Jensen et al., 1971). To the best of our knowledge, the current study is the first to demonstrate CDM effects in correct memory using DRM lists. Experiment 2 also demonstrated significant effects of context in false memory, but in the opposite direction to the effects observed in true memory. Specifically, reinstating the study context at test led to lower levels of false recall relative to the changed-context conditions. This is broadly consistent with the finding reported by Goodwin (2013; Experiment 3) that reinstating encoding strategies at test reduced false recall levels. The current study is the first, however, to demonstrate an effect of environmental context in false recall.

Previous studies have shown that false memories of critical lures in the DRM paradigm are frequently accompanied by the illusory recollection of contextual details, such as attributes of the critical lures (Gallo et al., 2001; Lyle & Johnson, 2006) and of the person who ostensibly spoke them at study (Lampinen et al., 1999; Payne, et al., 1996; Roediger, et al., 2004). The findings from the current study indicate that this effect is not enhanced, and is in fact reversed, when the encoding context is reinstated at retrieval. It is important to note, however, that in studies that have reported illusory recollection of contextual details, participants were explicitly asked whether they could recall such details. In the current study, the context was incidental to the experimental task and participants were not asked to recall it. Thus, while participants may falsely recall contextual information, possibly as a result of source monitoring errors (Lyle & Johnson), the current findings suggest that they do so only when explicitly asked to report it.

The current findings are consistent with the findings of Cann and Ross (1989) that changed odour contexts led to lower hit rates and higher false alarm rates than same odour contexts. Cann and Ross interpreted their findings in terms of an activation-level model, whereby the presence of an odour leads to an increase in activation. Although Cann and Ross did not discuss what exactly is activated by the odours, they suggest that activation functions in the same way as physiological changes. This is consistent with the conclusion drawn by Herz and Engen (1996) that odours produce changes in affect, which can enhance memory. Cann and Ross suggested that the presence of any odour enhances activation, thereby increasing both hits and false alarms. In contrast, reinstating the study odour at test enhances discrimination, thereby increasing correct recall. As we did not include a no-odour condition, we cannot confirm that the presence of any odour increased activation. However, our findings are consistent with the view that reinstating the study odour at test enhances discrimination.

An alternative explanation is that the change of context at retrieval impaired the accuracy of source monitoring processes. This would be consistent with previous findings that false memories increase when retrieval processes are disrupted. For example, Knott and Dewhurst (2007) found that divided attention at test increased false recollection as measured by *remember* responses (see Gardiner, 1988; Tulving, 1985). Knott and Dewhurst interpreted their findings in terms of the distinction between automatic and controlled source monitoring processes proposed by Mather, Henkel, and Johnson (1997). Automatic source monitoring decisions are made rapidly and accurately on the basis of perceptual details or matches to pre-existing knowledge in the form of schemas or templates. In contrast, controlled source monitoring decisions, otherwise referred to as heuristic-systematic processing (see Mitchell & Johnson, 2009 for a thorough review) are slower and more effortful judgements made in the absence of perceptual details or pre-existing knowledge. Mather et al. argued that effortful decisions are vulnerable to disruption and therefore more error prone than automatic decisions. In relation to the findings from Experiment 2, it is possible that reinstating the study context at test facilitated automatic source monitoring decisions based on perceptual details. This is supported by findings that odour cues, relative to verbal and visual cues, enhance the amount of perceptual detail retrieved in the recall of autobiographical memories (Chu & Downes, 2000, 2002). In the absence of such cues in the changed context condition, participants will have had to rely more on heuristic-systematic source monitoring decisions, which are more error prone than automatic decisions.

An unanticipated finding from Experiment 2 was the significant main effect of study odour on false recall, whereby rosemary produced higher levels of false recall than lemon. As discussed by Ball et al. (2010), there are anecdotal claims that rosemary has memory-enhancing properties (see, for example, Tisserand, 1977). The current study, however, showed that rosemary increased false recall rather than correct recall. One possible explanation of this finding is that rosemary enhances relational processing (see Hunt & Einstein, 1981, for the distinction between relational and item-specific processing). Previous research has shown that relational processing enhances correct recall (e.g., Guynn, McDaniel, Strosser, Ramirez, Castleberry, & Arnett (2014). However, when DRM lists are studied, relational processing has been shown to increase false recall rather than correct recall (e.g., McCabe, Presmanes, Robertson, & Smith, 2004; Huff & Bodner, 2011).

The pattern observed in Experiment 2, that reinstating the study context at test increased correct memory and reduced false memory, has clear implications for eyewitness testimony. Eyewitnesses are typically required to recall information in a context (e.g., a courtroom) that is different from the one in which they witnessed the event (e.g., the scene of a crime). Instructing eyewitnesses to mentally reinstate the context, including sensory details such as sounds and smells that were present, is one of the components of the Cognitive Interview (Geiselman et al., 1984), along with other strategies such as recalling the event from different perspectives and from different starting points. Subsequent research has shown that context reinstatement is the most effective component of the Cognitive Interview in terms of enhancing recall (see Memon & Higham, 1999, for a review). The current findings, albeit from a verbal learning experiment, support this view by showing that the reinstatement of a sensory context enhances memory accuracy by simultaneously increasing correct recall and reducing false recall.

The two dominant theoretical accounts of the DRM illusion are activation-monitoring theory (AMT; Roediger, Watson, McDermott, & Gallo, 2001) and fuzzy-trace theory (FTT; see Brainerd & Reyna, 2002). Although we did not set out to arbitrate between these theories, it is interesting to consider the current findings in relation to them. According to AMT, critical lures are spontaneously generated at study in response to list items. When the lures are presented at test, participants make errors of source monitoring (see Johnson, Hashtroudi, & Lindsay, 1993) and falsely endorse them as old. The monitoring component of AMT can be compared to the discrimination process proposed by Cann and Ross (1989) discussed above, which they argued is responsible for the increased recall accuracy when a study odour is reinstated. This appears to contradict the proposal by Lyle and Johnson (2006) that the illusory recollection of contextual details is the result of source monitoring errors. The critical factor appears to be whether or not the context is reinstated at test. When participants are required to recall contextual details without reinstatement of context, these details are misattributed to the critical lures. However, reinstatement of the study context boosts monitoring processes and enhances recall accuracy. Clearly, the recall of contextual detail and the functional role of context as a mnemonic aid are separate issues. Future research bridging this gap should reveal more about the role of context in memory.

According to FTT (Brainerd & Reyna, 2002), participants encode two traces of study items; verbatim traces that preserve contextual details of individual items and gist traces that represent the overall theme of the list. The DRM illusion occurs when participants falsely recall or recognise critical lures because they are consistent with the gist trace. However, participants can reject critical lures if they recollect verbatim traces of the corresponding studied items (Brainerd, Reyna, Wright, & Mojardin, 2003). This recollection rejection strategy can explain the current findings if one assumes that the reinstatement of study context strengthens the verbatim traces of the studied items.

To summarise, the current study is the first, to the best of our knowledge, to investigate the effects of environmental context manipulations on the false memories produced by the DRM procedure. Reliable CDM effects were observed in correct recall, indicating that the mnemonic benefits of context reinstatement extend to the associated word lists used in the DRM procedure. In addition to enhancing the numbers of words correctly recalled, context reinstatement increased the accuracy of memory by reducing susceptibility to false recall. As noted above, an experimental manipulation that simultaneously increases correct memory and reduces false memory has clear forensic value. A useful aim for future research will be to investigate whether this pattern extends to more naturalistic false memory paradigms.

References

Baker, J.R., Bezance, J.B., Zellaby, E., & Aggleton, J. P. (2004). Chewing gum can produce context-dependent effects upon memory. *Appetite*, *43*, 207–210. DOI:10.1016/j.appet.2004.06.004.

Ball, L.J, Shoker, J., Miles, J.N.V. (2010). Odour-based context reinstatement effects with indirect measures of memory: The curious case of rosemary. *British Journal of Psychology, 101*, 655-678. DOI:10.1348/000712609X479663.

Brainerd, C.J., & Reyna, V.F. (2002). Fuzzy-trace theory and false memory. *Current Directions in Psychological Science*, *11*, 164-169.

Brainerd, C.J., Reyna, V.F., Wright, R., & Mojardin, A.H. (2003). Recollection rejection: false-memory editing in children and adults. *Psychological Review*, *110*, 762-784. DOI:10.1037/0033-295X.110.4.762.

Cann, A., & Ross, D.A. (1989). Olfactory stimuli as context cues in human memory. *American Journal of Psychology*, *102*, 91–102. DOI:10.2307/1423118.

Chu, S., & Downes, J. J. (2000). Long live Proust: The odour-cued autobiographical memory bump. *Cognition*, *75*, B41-B50. DOI:10.1016/S0010-0277(00)00065-2.

Chu, S., & Downes, J. J. (2002). Proust nose best: Odors are better cues of autobiographical memory. *Memory & Cognition*, *30*, 511-518. DOI:10.3758/BF03194952.

Dalton, P. (1993). The role of stimulus familiarity in context-dependent recognition. *Memory & Cognition*, *21*, 223–234. DOI:10.3758/BF03202735.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology*, *58*, 17–22. DOI:10.1037/h0046671.

Fernandez, A., & Glenberg, A.M. (1985). Changing environmental context does not reliably affect memory. *Memory & Cognition, 13*, 333-345. DOI: 10.3758/BF03202501.

Gallo, D.A. (2010). False memories and fantastic beliefs: 15 years of the DRM illusion. *Memory & Cognition, 38,* 833–848. DOI: 10.3758/MC.38.7.833.

Gallo, D.A., McDermott, K.B., Percer, J.M., & Roediger, H.L., III. (2001). Modality effects in false recall and false recognition. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 27*, 339– 353. DOI: 10.1037/0278-7393.27.2.339.

Gardiner, J.M. (1988). Functional aspects of recollective experience. *Memory & Cognition, 16*, 309-313. DOI: 10.3758/BF03197041.

Geiselman, R.E., Fisher, R.P., Firstenberg, I. Hutton, L.A., Sullivan, S.J., Avetissain, I.V., & Prosk, A.L. (1984). Enhancement of eyewitness memory: An empirical evaluation of the cognitive interview. *Journal of Police Science and Administration, 12*, 74-80.

Godden, D.R., & Baddeley, A.D. (1975). Context-dependent memory in two natural environments: On land and underwater. *British Journal of Psychology, 66*, 325- 331. DOI:10.1111/j.2044-8295.1975.tb01468.x.

Goodwin, K. A. (2013). Reducing false memories via context reinstatement: The roles of encoding and retrieval contexts. *American Journal of Psychology, 126*, 213-225. DOI:10.5406/amerjpsyc.126.2.0213.

Guynn, M.J., McDaniel, M.A., Strosser, G.L., Ramirez, J.M., Castleberry, E.H., & Arnett, K.H. (2014). Relational and item-specific influences on generate–recognize processes in recall. *Memory & Cognition, 42*, 198-211. DOI:10.3758/s13421-013-0341-6.

Herz, R.S. (1997). The effects of cue distinctiveness on odor-based context-dependent memory. *Memory & Cognition, 25,* 375–380. DOI:10.3758/BF03211293.

Herz, R.S., & Engen, T. (1996). Odor memory: Review and analysis. *Psychonomic Bulletin & Review, 3*, 300-313. DOI:10.3758/BF03210754.

Huff, M.J., & Bodner, G.E. (2013). When Does Memory Monitoring Succeed Versus Fail? Comparing Item-Specific and Relational Encoding in the DRM Paradigm. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 1246- 1256. DOI:10.1037/a0031338.

Hunt, R.R., & Einstein, G.O. (1981). Relational and item-specific information in memory. *Journal of Verbal Learning & Verbal Behavior, 20*, 497–514. DOI:10.1016/S0022-5371(81)90138-9.

Jensen, L., Dibble, J., & Anderson, C. (1971). Effects of contextual change upon retroactive inhibition. *Psychological Reports*, *29*, 39-46. DOI:10.2466/pr0.1971.29.1.39.

Jerabek, I., & Standing, L. (1992). Imagined test situations produce contextual memory enhancement. *Perceptual and Motor Skills, 75*, 400. DOI: 10.2466/pms.1992.75.2.400

Knott, L.M., & Dewhurst, S.A. (2007). The effects of divided attention at study and test on false recognition: A comparison of DRM and categorized lists. *Memory & Cognition*, *35*, 1954–1965. DOI:10.3758/BF03192928.

Lampinen, J. M., Neuschatz, J. S., & Payne, D. G. (1999). Source attributions and false memories: A test of the demand characteristics account. *Psychonomic Bulletin & Review, 6*, 130-135.

Lyle, K.B., & Johnson, M.K. (2006). Importing perceived features into false memories. *Memory, 14*, 197-213. DOI: 10.1080/09658210544000060.

Mather, M., Henkel, L.A., & Johnson, M.K. (1997). Evaluating characteristics of false memories: Remember/know judgments and memory characteristics questionnaires compared. *Memory & Cognition*, *25*, 826-837. DOI:10.3758/BF03211327.

McCabe, D.P., Presmanes, A.G., Robertson, C.L., & Smith, A.D. (2004). Item-specific processing reduces false memories. *Psychonomic Bulletin & Review, 11*, 1074-1079. DOI:10.3758/BF03196739.

McDermott, K. B. (1996). The persistence of false memories in list recall. *Journal of Memory & Language*, *35*, 212-230. DOI:10.1006/jmla.1996.0012.

Mead, K.M.L., & Ball, L.J. (2007). Music tonality and context-dependent recall: The influence of key change and mood mediation*. European Journal of Cognitive Psychology, 19*, 59–79. DOI:10.1080/09541440600591999.

Memon, A., & Higham, P.A. (1999) A review of the cognitive interview. *Psychology, Crime & Law*, *5*, 177-196. DOI: 10.1080/10683169908415000

Miles, C., & Hardman, E. (1998). State-dependent memory produced by aerobic exercise. *Ergonomics*, *40*, 20-28. DOI:10.1080/001401398187297.

Moss, A., Miles, C., Elsley, J. & Johnson, A. (2016). Odorant normative data for use in olfactory memory experiments: Dimension selection and analysis of individual differences. *Frontiers in Psychology*, 7, 1267. DOI:10.3389/fpsyg.2016.01267.

Mitchell, K. J., & Johnson, M. K. (2009). Source monitoring 15 years later: what have we learned from fMRI about the neural mechanisms of source memory?. *Psychological bulletin*, *135*(4), 638. DOI: 10.1037/a0015849

Parker, A., Ngu, H., & Cassady, H.J. (2001). Odour and proustian memory: Reduction of context-dependent forgetting and multiple forms of memory. *Applied Cognitive*

Psychology, 15, 159-171. DOI: 10.1002/1099-0720(200103/04)15:2<159::AID-ACP694>3.0.CO;2-D.

Payne, D.G., Elie, C.J., Blackwell, J.M., & Neuschatz, J.S. (1996). Memory illusions: Recalling, recognizing, and recollecting events that never occurred. *Journal of Memory & Language, 35,* 261–285. DOI:10.1006/jmla.1996.0015.

Roediger, H. L., III, & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21*, 803–814. DOI:10.1037/0278-7393.21.4.803.

Roediger, H.L., III, McDermott, K.B., Pisoni, D.B., & Gallo, D.A. (2004). Illusory recollection of voices. *Memory, 12,* 586-602. DOI:10.1080/09658210344000125.

Roediger, H. L., III, Watson, J. M., McDermott, K. B., & Gallo, D. A. (2001). Factors that determine false recall: a multiple regression analysis. *Psychonomic Bulletin & Review, 8,* 385-407. DOI:10.3758/BF03196177.

Schab, F.R. (1990). Odors and the remembrance of things past. *Journal of Experimental Psychology: Learning, Memory & Cognition, 16,* 648- 655. DOI:10.1037/0278-7393.16.4.648.

Smith, S.M. (1979). Remembering in and out of context. *Journal of Experimental Psychology: Human Learning & Memory, 5*, 460-471. DOI:10.1037/0278-7393.5.5.460.

Smith, S.M. (1985). Effects of number of study environments and learning instructions on free-recall clustering and accuracy. *Bulletin of the Psychonomic Society*, 23, 440-442. DOI:10.3758/BF03329846.

Smith, S.M. (1988). Environmental context-dependent memory. In G.M. Davis & D.M. Thompson (Eds), *Memory in context: Context in memory*, pp. 13-34, New York, Wiley.

Smith, S.M. (1994). Theoretical principles of context-dependent memory. In P. Morris & M. Gruneberg (Eds.), *Theoretical aspects of memory* (2nd ed., pp. 168-195). London, England: Routledge.

Smith, S.M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review, 8,* 203-220. DOI:10.3758/BF03196157.

Smith, S.M., Glenberg, A., & Bjork, R.A. (1978). Environmental context and human memory. *Memory & Cognition, 6,* 342-353. DOI:10.3758/BF03197465.

Stadler, M.A., Roediger, H.L., & McDermott, K.B. (1999). Norms for word lists that create false memories. *Memory & Cognition, 27,* 494-500. DOI:10.3758/BF03211543.

Thompson, L.A., Williams, K.L., L'Esperance, P.R., & Cornelius, J. (2001) Context- dependent memory under stressful conditions: The case of skydiving. *Human Factors, 43,* 611-619. DOI:10.1518/001872001775870377.

Tisserand, R. (1977). *The art of aromatherapy*. Saffron Walden: C.W. Daniel.

Treisman, A. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12,* 242-248. DOI:10.1080/17470216008416732.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychologist, 26,* 1-12. DOI: 10.1037/h0080017.

Table 1

Mean numbers (with standard deviations) of studied items correctly recalled and critical lures falsely recalled as a function of study and test contexts for Experiment 1.

	Test context			
	Correct recall		*False recall*	
Study context	*Rosemary*	*Cinnamon*	*Rosemary*	*Cinnamon*
Rosemary	20.23 (5.14)	19.23 (4.47)	1.91 (1.27)	1.77 (1.31)
Cinnamon	16.41 (6.40)	20.18 (4.74)	2.23 (1.20)	1.64 (1.40)

Table 2

Mean numbers (with standard deviations) of studied items correctly recalled and critical lures falsely recalled as a function of study and test contexts for Experiment 2.

	Test context			
	Correct recall		*False recall*	
Study context	*Rosemary*	*Lemon*	*Rosemary*	*Lemon*
Rosemary	20.58 (7.34)	14.08 (4.66)	2.12 (1.99)	3.50 (1.27)
Lemon	13.27 (5.42)	21.96 (5.80)	2.69 (1.89)	1.42 (1.50)