

Individual Differences in Susceptibility to False Memory in the Deese–Roediger–McDermott Paradigm

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The authors addressed whether individual differences in the working memory capacity (WMC) of young adults influence susceptibility to false memories for nonpresented critical words in the Deese–Roediger–McDermott associative list paradigm. The results of 2 experiments indicated that individuals with greater WMC recalled fewer critical words than individuals with reduced WMC when participants were forewarned about the tendency of associative lists (e.g., *bed, rest, . . .*) to elicit illusory memories for critical words (e.g., *sleep*). In contrast, both high and low WMC participants used repeated study–test trials to reduce recall of critical words. These findings suggest that individual differences in WMC influence cognitive control and the ability to actively maintain task goals in the face of interfering information or habit.

There has been considerable recent interest in the nature of falsely remembered information that was never directly presented to an individual. This interest has been nurtured in part by Roediger and McDermott (1995), who adapted an experimental technique originally developed by Deese (1959), hereafter referred to as the Deese–Roediger–McDermott (DRM) paradigm. Roediger and McDermott presented participants with lists of 15 words that were the strongest associates to a missing word in free association norms (Russell & Jenkins, 1954). For example, participants might be presented with the following list of words, all of which are related to the nonpresented critical word *sleep*: *bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy*. Immediately following the presentation of a study list, participants recalled as many of the list words as

possible in any order (i.e., free recall with a warning against guessing). Despite this warning, participants typically recalled the nonpresented critical words with about the same probability as items that appeared in the middle of the study list. These remarkably high levels of false recall (and false recognition) have been widely replicated and extended (see Roediger, McDermott, & Robinson, 1998, for a partial review).

Activation-Monitoring Accounts of False Memories Elicited by the DRM Paradigm

False memories in the DRM paradigm may result in part from an automatic spread of activation from studied words (e.g., *bed, rest, awake*) to nonpresented but strongly associated critical words (e.g., *sleep*). As suggested by Balota et al. (1999), avoiding a false memory for a critical word requires one to differentiate between highly activated but nonpresented critical words and studied words. Hence, false memories in the DRM paradigm may also be due to a breakdown in attentional control or monitoring systems that differentiate the activation of critical words in associative networks from the actual presentation of words at encoding (for additional discussion of activation-monitoring frameworks of the DRM memory illusion, see McDermott & Watson, 2001; Roediger, Balota, & Watson, 2001; Roediger, Watson, McDermott, & Gallo, 2001; Watson, Balota, & Sergent-Marshall, 2001).¹

An activation-monitoring framework can be used to explain several findings in the DRM false memory literature. For example,

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¹ There are alternative accounts of how false memories are elicited in the DRM paradigm, including fuzzy-trace theory (Brainerd, Reyna, Wright, & Mojardin, 2003; Reyna & Brainerd, 1995) and the discrepancy-attribution hypothesis (Whittlesea & Masson, 2003; Whittlesea & Williams, 2001a, 2001b).

young adults can take advantage of explicit warning instructions given prior to encoding to reduce but not eliminate false memories (Gallo, Roberts, & Seamon, 1997; Gallo, Roediger, & McDermott, 2001; McDermott & Roediger, 1998; Neuschatz, Benoit, & Payne, 2003). Warnings inform participants that false memories are being elicited in the DRM paradigm through the presentation of associates of a single nonpresented critical word. As suggested by Gallo et al. (1997), warning instructions at encoding may encourage participants to monitor and tag missing critical words as not presented during study, thereby minimizing the likelihood of false memories. Using a multiple study–test trial procedure, McDermott (1996) demonstrated that veridical memory increased across repeated study–test trials, whereas false memory decreased. Within an activation-monitoring framework, young adults may use repeated study–test trials to verify what is presented and to determine what is strongly associated but not presented, gradually improving their veridical memory while concurrently diminishing but not eliminating their false memory with practice.

Individual Differences in Susceptibility to False Memory in the DRM Paradigm

The DRM paradigm has also been used to provide leverage on understanding the breakdowns in episodic memory that occur with healthy aging (Balota et al., 1999; Budson, Daffner, Desikan, & Schacter, 2000; Kensinger & Schacter, 1999; McCabe & Smith, 2002; Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998; Watson et al., 2001; Watson, McDermott, & Balota, 2004). In general, these studies have demonstrated that, compared with young adults, healthy older adults have impaired veridical memory but equivalent or enhanced false memory. The DRM paradigm has also been used to investigate the integrity of episodic memory, lexical processing, and source monitoring in various clinical groups (Baciu et al., 2003; Balota et al., 1999; Moritz, Woodward, Cuttler, Whitman, & Watson, 2004; Schacter, Verfaellie, & Pradere, 1996; Watson et al., 2001). With the exception of amnesic patients (Schacter et al., 1996), false memories elicited by the DRM paradigm appear to be remarkably robust across fairly diverse clinical populations, including individuals with schizophrenia (Moritz et al., 2004) and individuals with dementia of the Alzheimer's type (Balota et al., 1999; Watson et al., 2001). It is possible that healthy older adults and individuals with Alzheimer's disease experience breakdowns in the monitoring and/or attentional-inhibitory cognitive control systems that differentiate the overall activation from related words converging on a nonpresented critical word from the item-specific information of studied words (Balota et al., 1999; Hasher & Zacks, 1988; Johnson, Hashtroudi, & Lindsay, 1993; Watson et al., 2001).

Given the considerable amount of aging and clinical research that has been conducted with the DRM paradigm, it is surprising how few studies have explored whether individual differences in young adults influence the likelihood of false memories. To this point, the majority of the individual-differences research on young adults has focused on either the reliability of the DRM paradigm (Blair, Lenton, & Hastie, 2002) or whether variability in stimulus materials influences the probability of false memories. For example, some associative lists are more effective than others at eliciting false memories (Gallo & Roediger, 2002; Roediger, Watson, et al., 2001; Stadler, Roediger, & McDermott, 1999). When a warn-

ing is given about the DRM illusion prior to encoding, some lists are also more likely than others to have their corresponding critical words identified by participants and subsequently omitted from a recall or recognition memory test (Neuschatz et al., 2003). In another study of individual differences in young adults, Winograd, Peluso, and Glover (1998) found that self-reports of high levels of dissociative experiences and vivid mental imagery correlated with high levels of false memory. Although additional empirical work is necessary, Winograd et al.'s results suggest that some young adults may be more susceptible than others to false memories elicited by the DRM paradigm.

Individual Differences in Working Memory Capacity: A Controlled-Attention View

Kane and Engle (2002) argued that one of the primary functions of working memory is attentional control. Specifically, working memory or executive attention is used to maintain cognitive representations in an active state in the presence of interfering information. Kane and Engle (2002) suggested that these representations might reflect action plans, goal states, or other task-relevant stimuli in the environment. Hence, from an attentional-control perspective, one might expect individual differences in the working memory capacity (WMC) of young adults to influence behavioral performance in cognitively challenging tasks that require the active maintenance of task goals in the face of potentially interfering information. Consistent with this idea, individuals with low WMC (low spans) perform more poorly than individuals with high WMC (high spans) in situations where successful performance is dependent on minimizing interference, including fan effects, output interference, and proactive and retroactive interference paradigms (Conway & Engle, 1994; Kane & Engle, 2000; Rosen & Engle, 1997, 1998). Additional evidence of individual differences in executive, attentional control in young adults has been obtained through dichotic listening, the antisaccade task, and Stroop color naming (see Conway, Cowan, & Bunting, 2001; Kane, Bleckley, Conway, & Engle, 2001; Kane & Engle, 2003, respectively).

Using the Stroop (1935) color naming task, Kane and Engle (2003) demonstrated that low spans produced more naming errors than high spans in the incongruent condition (e.g., participants mistakenly say "red" when the stimulus *RED* is printed in green ink). However, with respect to motivating the predictions for the present study on WMC and false memories, it is noteworthy that this individual difference in young adult Stroop performance only emerged when 75% of the experimental trials were congruent (e.g., *GREEN* printed in green ink). That is, high and low spans performed similarly on the Stroop task under experimental conditions where the proportion of congruent trials was low. According to Kane and Engle (2003), it is more challenging to maintain the overarching task goal of color naming across the course of a Stroop experiment when participants are presented with a high proportion of congruent trials in which both the color and the word response match (and, hence, accurate responding is possible whether participants correctly name the ink color or incorrectly name the word that is printed on the computer screen). Therefore, in Stroop experiments in which the proportion of congruent trials is high, accuracy on incongruent trials should be sensitive to individual differences in cognitive control or the ability to successfully maintain the overarching task goal (color naming) and to

avoid the influence of interfering information or habit (word naming).

Experiment 1

The primary goal of the present study was to determine whether individual differences in the WMC of young adults influence susceptibility to false memories elicited by the DRM paradigm. As suggested by Kane and Engle's (2003) study of WMC and Stroop color naming performance, the ability to discriminate the behavioral performance of high and low spans may depend on the use of manipulations that emphasize the active maintenance of overarching task goals. To address this possibility, in Experiment 1 we factorially crossed WMC (high vs. low span) with warning instructions (present vs. absent) administered at encoding. Low span young adults may be less likely than high span young adults to reduce false memories for critical words in the DRM paradigm with warnings at encoding because of underlying group differences in the ability to actively maintain task goals (e.g., identify but do not recall nonpresented critical words) and to avoid the influence of habit (e.g., the relatively automatic activation of critical words in associative networks). In contrast, individual differences in the WMC of young adults may not influence susceptibility to false memories under standard learning conditions without a warning because of the relatively automatic activation of nonpresented critical words for both high and low spans. If this is the case, one might expect a Span \times Warning interaction in the probability of false recall of critical words in Experiment 1.

Method

Participants. In Experiment 1, undergraduates from the University of Illinois–Chicago were initially screened through the operation span task (La Pointe & Engle, 1990; Turner & Engle, 1989). In this task, participants are required to read aloud a math problem followed by a to-be-remembered word—for example, “Is $(8/4) + 3 = 4?$ DOG.” After varying numbers of these equation–word pairs, participants are prompted to recall all of the words included in each set in order. Trials were pseudorandomized such that participants could not predict the set size of upcoming equation–word trials. Participants were given points equal to the set size when all of the words in that set were recalled correctly in serial order. Operation span was defined as the sum of the points across all of the individual recall periods. For the purposes of the present study, 50 high and 50 low spans were identified from the upper and lower quartiles of the distribution of span scores from this initial screening session, respectively.²

Materials. Thirty-six 16-word lists of lexical–semantic associates were used in the present study. These 36 lists were originally developed by Watson, Balota, and Roediger (2003) for other purposes and have been shown to elicit false memories for nonpresented critical words (McDermott & Watson, 2001). For these semantic lists, list construction was modeled loosely after procedures used by Roediger and McDermott (1995), whereby the top associates to critical nonpresented words were collected. Although Roediger and McDermott and most other researchers have presented items in the order of strongest to weakest associates, in the present study, the 16 associates were presented in a single random order. Consistent with both McDermott and Watson (2001) and Watson et al. (2003), words in the odd-numbered serial positions were presented in uppercase letters, whereas words in the even-numbered positions were presented in lowercase (see McDermott & Watson, 2001, for additional discussion of why the case was changed across the 16-item list of associates and why a random order of associates was used in development of the Watson et al., 2003, stimuli).

Procedure. Each subject studied thirty-six 16-word lists, presented visually on a projection screen at a single duration (i.e., 1 s/word in the center of the screen, with a 32-ms blank screen interstimulus interval). Participants were tested in groups, with a maximum of 10 subjects per session. For each group of participants, the order of lists was randomly determined, but the order of words within each list was held constant across all participants. Participants received a test packet with instructions to study each 16-word list that appeared because they would receive a 45-s free recall memory test at the end of each list. Participants were also told not to guess when trying to remember the words from each list. Prior to the start of the experiment, all of the participants were given a practice list of semantic associates at the same presentation duration as the experimental lists to familiarize them with the testing procedures. As described below, half of the high and low spans were also given additional explicit warning instructions about the DRM false memory paradigm prior to encoding. The remaining half of the high and low spans in Experiment 1 were not given any warning, but they were otherwise treated identically to the warned participants. The between-subjects factorial crossing of WMC (high vs. low span) and warning instruction (present vs. absent) yielded a total of 25 participants per cell (with a grand total of 100 subjects tested in Experiment 1).

The warning manipulation in the present study was modeled after the instructions used by Gallo et al. (1997) and McDermott and Roediger (1998). Participants were warned that the forthcoming associative lists were designed to elicit false memories for particular critical words that were never presented. Participants were encouraged to avoid recalling the trick word for each of the 16-word associative lists. To make this instruction more concrete, prior to receiving the practice list, we told warned participants what the practice list would be (e.g., *beetle, spider, ant, pest, . . .*) and also gave them the identity of the nonpresented critical word (e.g., *bug*). Hence, if warned participants suspected that a critical word had merely been suggested, it was always correct to identify and to omit this word during free recall (see Gallo, Roediger, et al., 2001; McDermott & Roediger, 1998, for additional discussion of methodological issues regarding the presence of critical words in DRM experiments that use warnings).

Results

The mean veridical and false recall probabilities are presented in Figure 1 as a function of span and instruction. A series of 2 (span: high or low) \times 2 (warning: present or absent) analyses of variance (ANOVAs) were conducted on veridical recall, false recall of critical words, and other noncritical word intrusions, respectively. On the basis of Kane and Engle's (2003) study of WMC and goal maintenance, separate planned ANOVAs were also conducted to directly compare the false recall of critical words for the high and low spans in both the no warning (Figure 1A) and warning (Figure 1B) conditions of Experiment 1. Unless otherwise noted, the criterion for significance was set at .05 for all analyses discussed below.

Veridical recall. As shown in Figure 1, in general, high spans recalled more studied words (.49) than low spans (.44), and warned participants recalled slightly fewer studied words (.45) than non-

² Participants in Experiments 1 and 2 received one of two versions of the operation span task. In one version of this task, the set size varied between two and six math and word combinations per recall period, whereas in the second version, the set size varied between two and five combinations per recall period. In both experiments, when identifying the lower and upper quartiles in the distribution of span scores, low spans scored between 0 and 9 points on the operation span task, whereas high spans scored greater than 20 points, respectively.

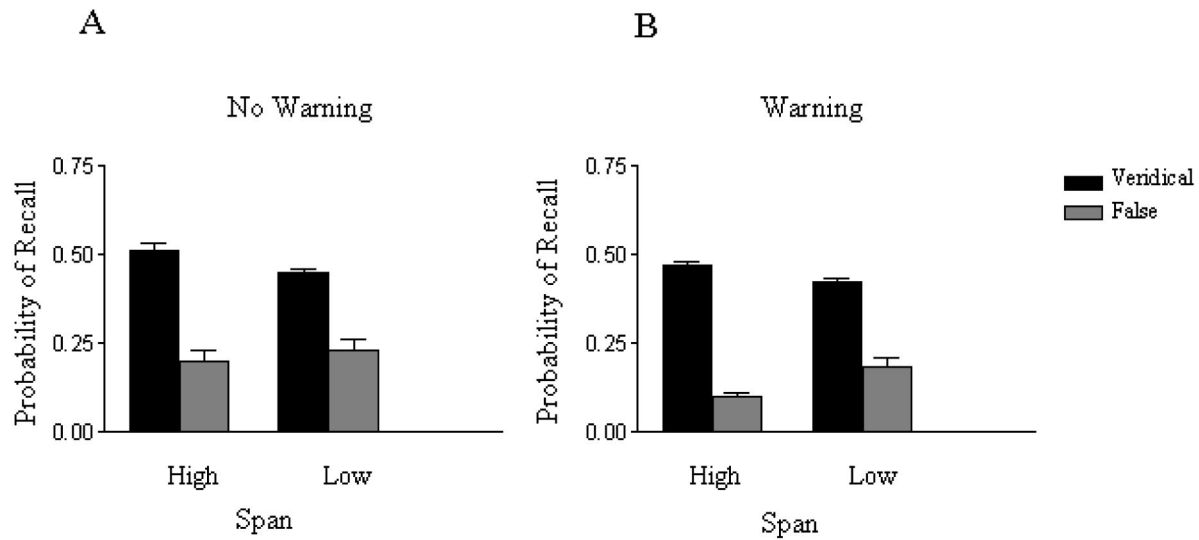


Figure 1. Mean veridical and false recall probabilities as a function of span and instruction. High and low span young adults did not differ in their recall of associated but nonpresented critical words from the Deese–Roediger–McDermott paradigm in the no warning condition (A), whereas high spans recalled fewer critical words than low spans in the warning condition (B). Error bars represent the standard error of the mean.

warned participants (.48). Consistent with these observations, a 2 (span) \times 2 (warning) ANOVA on veridical recall yielded a main effect of span, $F(1, 96) = 12.32$, $MSE = .006$, and a main effect of warning, $F(1, 96) = 5.20$, $MSE = .006$. The two-way interaction of span and warning did not approach significance ($F < 1.00$).

False recall of critical words. As shown in Figure 1, high spans recalled fewer critical words (.15) than low spans (.20), and warned participants recalled fewer critical words (.14) than nonwarned participants (.21). Consistent with these observations, a 2 (span) \times 2 (warning) ANOVA on false recall yielded a main effect of span, $F(1, 96) = 4.00$, $MSE = .017$, and a main effect of warning, $F(1, 96) = 7.21$, $MSE = .017$. Although the predicted two-way interaction of span and warning in false recall of critical words did not approach significance ($F < 1.00$), as shown in Figure 1A, a separate planned ANOVA indicated that when high and low spans were not given an explicit warning to avoid false memories in the DRM paradigm, false recall was roughly comparable across the two groups (.20 vs. .23 for high vs. low spans, respectively), $F(1, 48) = 0.38$, $MSE = .024$, $p = .54$. In contrast, as shown in Figure 1B, when participants were given a warning, high spans (.10) were less likely than low spans (.18) to recall the nonpresented critical words, $F(1, 48) = 7.09$, $MSE = .011$. Hence, preliminary evidence from the separate planned ANOVAs in the no warning and warning conditions of Experiment 1 suggests that individual differences in the WMC of young adults may influence the probability of false memories in the DRM paradigm. However, as expected, the ability to observe these individual differences may require the use of experimenter-provided warning instructions that are administered at encoding and designed to help participants inhibit or reduce their susceptibility to false memories.

Other noncritical word intrusions. A 2 (span) \times 2 (warning) ANOVA on the intrusions per list (not including the recall of critical words) yielded no significant main effects and no interaction (all F s < 1.39). Although the null effect of warning on

noncritical word intrusions seems reasonable given that the manipulation was specifically designed to reduce false memories for nonpresented critical words in the DRM paradigm, these results should be interpreted with caution, because the average noncritical word intrusion rate collapsed across all four cells of the present study was only .13 intrusions per list.

Discussion

A controlled-attention view of WMC suggests that individuals with greater WMC (high spans) may be able to exert cognitive control over false memories elicited by the DRM paradigm, thereby reducing the likelihood of these memory errors compared with individuals with reduced WMC (low spans). Consistent with this idea, the results of Experiment 1 indicate that high spans recalled fewer nonpresented critical words than low spans. However, it is noteworthy that individual differences in young adult susceptibility to false memory only emerged when participants were forewarned about the tendency of the associative lists in the DRM paradigm to elicit illusory memories for these critical words. Under standard learning conditions without a warning, high and low span young adults appeared to be equally susceptible to memory errors elicited by the DRM paradigm. In this way, the present study on false memory yields results analogous to those of Kane and Engle (2003), who observed increased Stroop naming errors for low relative to high span young adults, but only when they manipulated task goals by increasing the proportion of congruent trials.

Experiment 2

Although the separate planned ANOVAs comparing high and low span false recall of critical words in the no warning and warning conditions of Experiment 1 were justified on the basis of

Kane and Engle (2003), it is noteworthy that the predicted two-way interaction of span and warning in false recall was not significant. Given this finding, there may be an alternative explanation for the results of Experiment 1. Specifically, as shown in Figure 1, high spans recalled more studied words than low spans in both the no warning and the warning conditions. Consequently, high spans may be better than low spans at monitoring and reducing false recall of critical words in the DRM paradigm simply because of group differences in veridical recall at retrieval as opposed to group differences in goal maintenance of warnings administered at encoding (see Roediger, Watson, et al.'s, 2001, regression analysis for evidence that veridical and false recall are negatively correlated for associative lists and their corresponding critical words, respectively).

In this light, the goals of Experiment 2 were twofold. First, we attempted to buttress the conclusion from Experiment 1 that high span young adults can use warnings administered at encoding to reduce false recall of critical words in the DRM paradigm, whereas low span young adults cannot, by demonstrating a statistically significant two-way interaction of span and warning in Experiment 2 (with no group differences predicted in false recall for the standard, no warning condition). Second, to follow up on the alternative explanation of the results of Experiment 1 and gain empirical leverage on what role veridical recall might play in reducing false recall in the DRM paradigm for high and low span young adults, we incorporated a repeated study–test trial procedure in the design of Experiment 2 (McDermott, 1996; Watson et al., 2004). As noted earlier, within an activation-monitoring framework, young adults may use repeated study–test trials to verify what is presented and to determine what is strongly associated but not presented in the DRM paradigm, gradually improving their veridical memory while concurrently diminishing but not eliminating their false memory with practice. From an attentional-control perspective, unlike warning manipulations, which may require the active maintenance of task goals to attenuate false memories, repeated study–test trial manipulations may rely on a somewhat different monitoring mechanism, such as an individual's ongoing experience or practice with the associative lists (see Watson et al., 2004, for additional discussion of the similarities and differences in warning and repeated study–test trial manipulations in the DRM paradigm). If this is the case, although the low span young adults in Experiment 2 might not use experimenter-provided warnings administered at encoding to reduce false recall, they might use their own memory performance at retrieval to spontaneously reduce false recall of critical words.

Method

Participants. In Experiment 2, undergraduates from the University of Illinois–Chicago were initially screened through the operation span task (La Pointe & Engle, 1990; Turner & Engle, 1989). As in Experiment 1, 50 high and 50 low spans were identified from the upper and lower quartiles of the distribution of span scores from this initial screening session, respectively. Although subjects were selected from similar points in the distribution of operation span scores, the 100 participants tested in Experiment 2 did not overlap with the 100 participants tested in Experiment 1.

Materials. Four 15-word sets of associates were blocked according to their related critical word (i.e., *smell*, *doctor*, *window*, and *sleep*, where *smell* was the corresponding critical word from the first set of 15 associates, *doctor* for the next set of 15 associates, and so forth). Compared with

the set of stimuli used in Experiment 1, these four lists and critical words may elicit more robust levels of false recall on the basis of normative data previously collected on young adults (see Stadler et al., 1999). Furthermore, the critical words from these four lists could be considered moderately to highly identifiable. Specifically, Neuschatz et al. (2003) recently found that, on average, when a warning was given, the corresponding nonpresented critical words from these four DRM associative lists were correctly identified by approximately 64% of the participants.

Procedure. The 60-word list was digitally recorded in a male voice, and the same recording was used for all study phases. Presentation modality at study was switched from visual in Experiment 1 to auditory in Experiment 2 because auditory presentation has been shown to elicit more false memories than visual presentation in the DRM paradigm (Gallo, McDermott, Percer, & Roediger, 2001; Kellogg, 2001; Smith & Hunt, 1998). Stimuli were presented aurally through headphones worn by participants. For all participants, the 60-word list was presented at an approximate rate of 1 word every 1.25 s. Participants were tested individually. As described below, half of the high and low spans were given explicit warning instructions about the DRM paradigm prior to encoding. The remaining half of the high and low spans were not given any warning, but they were otherwise treated identically to the warned participants. The between-subjects factorial crossing of WMC and warning yielded a total of 25 participants per cell (with a grand total of 100 subjects tested in Experiment 2). Study–test trial was manipulated within subjects.

As in Experiment 1, the warning manipulation was modeled after the instructions used by Gallo et al. (1997) and McDermott and Roediger (1998). Participants were warned that the forthcoming associative lists were designed to elicit false memories for particular critical words that were never presented. Participants were encouraged to avoid recalling the trick word for each of the four sets of 15 words that had been combined to form the 60-word list. To make this warning more concrete, we gave participants a sample list (i.e., *chair*; see Stadler et al., 1999) at the same presentation rate as the forthcoming study list. Hence, if participants suspected that a critical word had merely been suggested, it was always correct to omit this word during free recall. Nonwarned participants were also informed that they would receive sets of associate lists and also received the sample list (but *chair* was not identified as a nonpresented trick word, as it was for warned participants).

Participants were given a test packet that contained five different response sheets with 60 numbered blanks per sheet. Participants were given instructions to study each 60-word list because they would receive a 5-min free recall memory test at the end of each list. Participants were told to try to improve their memory performance with each successive study episode of the 60-word list and were told not to guess when trying to remember the words from each list. Before each of the five study episodes, warned participants were also instructed about the tendency for DRM lists to elicit recall of nonpresented trick words.

Results

The mean veridical and false recall probabilities are presented in Figure 2 as a function of span, study–test trial, and instruction. A series of 2 (span: high or low) \times 2 (warning: present or absent) \times 5 (study–test trial: one through five) mixed-factor ANOVAs were conducted on veridical recall, false recall of critical words, and other noncritical word intrusions, respectively. On the basis of Kane and Engle's (2003) study of WMC and goal maintenance, separate planned 2 (span) \times 5 (study–test trial) mixed-factor ANOVAs were also conducted to directly compare the false recall of critical words for the high and low spans in both the no warning (Figure 2A) and warning (Figure 2B) conditions of Experiment 2. Unless otherwise noted, the criterion for significance was set at .05 for all analyses discussed below.

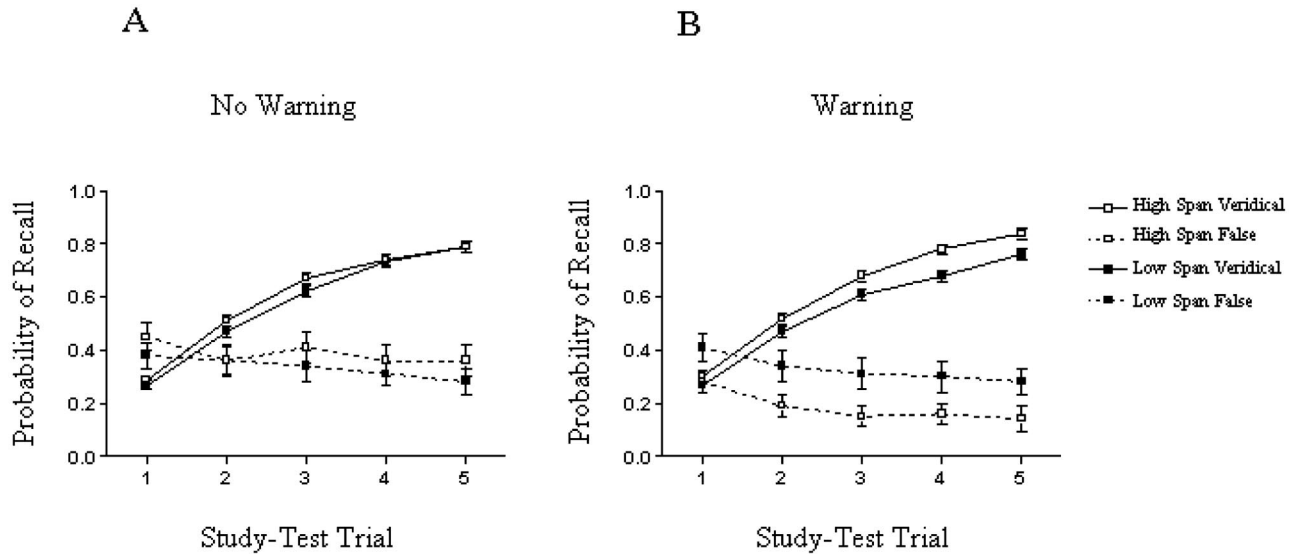


Figure 2. Mean veridical and false recall probabilities as a function of span, study-test trial, and instruction. Consistent with the results of Experiment 1, high and low span young adults did not differ in their recall of associated but nonpresented critical words from the Deese-Roediger-McDermott paradigm in the no warning condition (A), whereas high spans recalled fewer critical words than low spans in the warning condition (B). In contrast to the warning results, both high and low spans used repeated study-test trials or practice to reduce recall of critical words. Error bars represent the standard error of the mean.

Veridical recall. As shown in Figure 2, consistent with the results of Experiment 1, high spans recalled more studied words (.61) than low spans (.57), and, in general, participants recalled more studied words from the first (.28) to the fifth study-test trial (.79). Consistent with these observations, a 2 (span) \times 2 (warning) \times 5 (study-test trial) ANOVA yielded a main effect of span, $F(1, 96) = 7.26$, $MSE = .036$, and a main effect of study-test trial, $F(4, 384) = 1,483.74$, $MSE = .003$. However, these two main effects were qualified by the three-way interaction of span, warning, and study-test trial, which indicated that high spans increased their veridical recall by a greater amount across trials than the low spans, but only in the warning condition, $F(4, 384) = 2.63$, $MSE = .003$. The main effect of warning and the remaining interactions in this ANOVA did not approach significance (all $ps > .11$).

To further investigate the nature of the observed three-way interaction of span, warning, and study-test trial in Experiment 2, we conducted additional 2 (span) \times 5 (study-test trial) mixed-factor ANOVAs on veridical recall in the no warning and warning conditions, and these ANOVAs revealed four important points. First, as shown in Figure 2A, collapsed across study-test trial, high spans (.60) and low spans (.57) did not differ in their recall of studied words in the standard, no warning condition, $F(1, 48) = 1.11$, $MSE = .035$, $p = .30$. Second, in contrast, as shown in Figure 2B, collapsed across study-test trial, high spans recalled more studied words (.62) than low spans (.56) in the warning condition, $F(1, 48) = 7.54$, $MSE = .036$. Third, as shown in Figure 2, in both the no warning and the warning conditions, collapsed across working memory span, veridical recall increased across repeated study-test trials, $F(4, 192) = 743.51$, $MSE = .003$, and $F(4, 192) = 740.59$, $MSE = .003$, respectively. Fourth, as shown in Figure 2A, high and low span veridical recall was

roughly equivalent across repeated study-test trials in the no warning condition, $F(4, 192) = 2.01$, $MSE = .003$, $p = .10$; however, as shown in Figure 2B, the high span advantage in veridical recall appeared to increase slightly with repeated study-test trials in the warning condition, $F(4, 192) = 2.53$, $MSE = .003$.

False recall of critical words. As shown in Figure 2, warned participants recalled fewer critical words (.26) than nonwarned participants (.36), and, in general, participants recalled fewer critical words from the first (.38) to the fifth study-test trial (.27). Consistent with these observations, a 2 (span) \times 2 (warning) \times 5 (study-test trial) ANOVA yielded a main effect of warning, $F(1, 96) = 6.27$, $MSE = .219$, and a main effect of study-test trial, $F(4, 384) = 6.46$, $MSE = .029$. More important, as predicted, the statistically significant two-way interaction of span and warning indicated that high spans decreased their recall of critical words in the warning (.18) relative to the no warning condition (.39), whereas low span false recall was not influenced by the warning manipulation ($\cong .33$), $F(1, 96) = 5.58$, $MSE = .219$. The main effect of span and the remaining interactions in this ANOVA did not approach significance (all $ps > .29$).

Additional planned 2 (span) \times 5 (study-test trial) mixed-factor ANOVAs on false recall of critical words in the no warning and warning conditions revealed five important points. First, as shown in Figure 2A, when high and low span young adults were not given an explicit warning to avoid false memories in the DRM paradigm, false recall was roughly comparable across the two groups ($\cong .36$ collapsed across study-test trial and span), $F(1, 48) = 0.70$, $MSE = .262$, $p = .41$. Second, in contrast, as shown in Figure 2B, when participants were given a warning prior to encoding the DRM lists, high spans (.18) were less likely than low spans (.33) to recall the nonpresented critical words, $F(1, 48) = 7.28$,

$MSE = .178$. Hence, as predicted and consistent with the preliminary results of Experiment 1, individual differences in the WMC of young adults influenced the probability of false recall in the DRM paradigm. Furthermore, additional ANOVAs on the warning factor confirmed that high spans used the warning to reduce their recall of nonpresented critical words, $F(1, 48) = 11.07$, $MSE = .235$, whereas low spans did not, $F(1, 48) = .01$, $MSE = .205$, $p = .92$. Third, as shown in Figure 2, in both the no warning and the warning conditions, in contrast to the pattern observed in veridical recall, false recall decreased across repeated study–test trials, $F(4, 192) = 2.22$, $MSE = .031$, $p < .07$, and $F(4, 192) = 4.94$, $MSE = .029$, respectively. Moreover, additional ANOVAs indicated that both high and low spans used repeated study–test trials to decrease the probability of false recall, $F(4, 192) = 4.66$, $MSE = .022$, and $F(4, 192) = 2.60$, $MSE = .037$, respectively. Specifically, collapsed across the no warning and warning conditions in Figure 2, high span false recall decreased from .37 to .25 for the first to the fifth study–test trial, respectively, whereas low span false recall decreased from .40 to .28. In this way, the results of Experiment 2 yielded a dissociation in which low span young adults benefited from practice but not warnings designed to reduce false memories in the DRM paradigm, whereas high span young adults benefited from both manipulations. Fourth, in both the no warning and the warning conditions, for both high and low spans, false recall decreased across repeated study–test trials (i.e., both F s < 1.00 for the Study–Test Trial \times Span interaction). Fifth, separate ANOVAs on false recall for the high and low spans indicated that warnings and repeated study–test trials did not interact for either group (i.e., both F s < 1.00 for the Study–Test Trial \times Warning interaction).

Other noncritical word intrusions. A 2 (span) \times 2 (warning) \times 5 (study–test trial) ANOVA was conducted on the raw number of intrusions per test (not including the recall of critical words). However, caution is warranted in interpreting these intrusion data because the mean raw number of intrusions collapsed across all of the independent variables in the present study was quite low ($\cong .49$ items/test) considering that participants studied a 60-item word list at encoding. Nevertheless, as one might expect with repeated study episodes, intrusions decreased from the first (.94) to the fifth study–test trial (.23), $F(4, 384) = 20.62$, $MSE = .412$. The two-way interaction of span and study–test trial also approached significance, $F(4, 384) = 2.12$, $MSE = .412$, $p = .08$, indicating that intrusions may have decreased slightly more for low spans (1.18 to 0.28) than for high spans (0.70 to 0.18) from the first to the fifth study–test trial, respectively. The remaining main effects and interactions in this ANOVA did not approach significance (all p s $> .13$). Consistent with Experiment 1, the null effect of warning on noncritical word intrusions in Experiment 2 seems reasonable given that the manipulation was specifically designed to reduce false memories for nonpresented critical words in the DRM paradigm.

Discussion

There were two main findings in Experiment 2. First, consistent with a controlled-attention view of individual differences in WMC (Kane & Engle, 2002), the statistically significant two-way interaction of span and warning indicated that high span young adults

used warnings administered at encoding to reduce false recall of critical words in the DRM paradigm, whereas low span young adults did not. Second, in contrast to these warning results, both high and low span young adults used repeated study–test trials to reduce but not eliminate the recall of nonpresented critical words in the DRM paradigm. Hence, in addition to replicating the individual differences in susceptibility to false memories that we observed in Experiment 1, as predicted, Experiment 2 yielded a dissociation in which low span young adults benefited from practice but not warnings designed to reduce false memories in the DRM paradigm (whereas high span young adults clearly benefited from both manipulations). Taken together, these results suggest that despite breakdowns in the ability to actively maintain task goals (e.g., using experimenter-provided warnings administered at encoding to reduce susceptibility to false memories), low spans have a preserved ability to engage in spontaneous, self-initiated source monitoring (e.g., using practice with the associative lists and their own memory performance at retrieval to reduce false memories elicited by the DRM paradigm).

General Discussion

The primary goal of the present study was to determine whether individual differences in the WMC of young adults influence susceptibility to false memories. To achieve this goal, we tested 200 high and low span young adults using the DRM false memory paradigm, in which lists of associates (e.g., *bed, rest, awake, . . .*) converge on and activate a nonpresented critical word (e.g., *sleep*). To influence the likelihood of false memories, we included warning instructions at encoding (Experiments 1 and 2) and repeated study–test trials (Experiment 2), both of which are thought to influence the source monitoring or attentional–inhibitory control component of an activation-monitoring framework of false memories in the DRM paradigm (Balota et al., 1999; Watson et al., 2004).

Individual Differences, Warnings, and False Memories in the DRM Paradigm

Winograd et al. (1998) found that self-reports of high levels of dissociative experiences and vivid mental imagery correlated with high levels of false recognition for nonpresented critical words in the DRM paradigm. Although these results suggest that some young adults may be more susceptible than others to false memories elicited by the DRM paradigm, it is noteworthy that individual differences in 10 different cognitive (e.g., vocabulary, memory, and aptitude tests) or personality measures (e.g., the Dissociative Experiences Scale; Bernstein & Putnam, 1986) did not correlate with participants' false recall of critical words. More important for the purposes of the present study, Winograd et al. did not include a measure of WMC in the design of their experiment (e.g., operation span; Turner & Engle, 1989). Hence, on the basis of Winograd et al.'s findings, it is unclear whether individual differences in the WMC of young adults influence susceptibility to false memories in the DRM paradigm.

To determine whether individual differences in the WMC of young adults influence susceptibility to false memories in the DRM paradigm, in the present study we factorially crossed WMC

(high vs. low span) with warning instructions (present vs. absent) administered at encoding. From a controlled-attention perspective, one might expect individual differences in the WMC of young adults to influence behavioral performance in cognitively challenging tasks that require the active maintenance of task goals in the face of potentially interfering information (Kane & Engle, 2002). Consistent with this hypothesis, the results of Experiments 1 and 2 indicate that high spans recalled fewer nonpresented critical words than low spans. However, individual differences in susceptibility to false memory only emerged when participants were forewarned about the tendency of the associative lists to elicit illusory memories for nonpresented critical words (with no difference observed between high and low span false recall in the standard, no warning condition of the DRM paradigm; see Figures 1 and 2). Furthermore, the statistically significant two-way interaction of span and warning demonstrated in Experiment 2 ruled out the alternative explanation of the results of Experiment 1, in which one might have argued that the individual differences we observed in false recall were due to group differences in veridical recall at retrieval for the high and low span young adults. Moreover, the pattern of results observed in the present study cannot simply be attributed to the selection of extreme groups of young adults from our distribution of operation span scores or simple scaling effects, independent of the presence of a warning at encoding. Rather, the idea is that WMC is a proxy for cognitive control (Kane & Engle, 2002). Following this logic, high and low spans differ in their ability to actively maintain task goals (e.g., identify but do not recall the nonpresented critical words) and, hence, are more susceptible to the influence of habit (e.g., the relatively automatic activation of critical words in associative networks in the DRM paradigm).

The findings of the present study also appear to constrain the potential effectiveness of warning instructions intended to reduce false memories elicited by the DRM paradigm. Although young adults have been shown to reduce but not eliminate false memories in the DRM paradigm when given detailed warning instructions at encoding (Gallo et al., 1997; McDermott & Roediger, 1998), the results of the present study suggest that low span young adults are unlikely to reduce false memories with these detailed warning instructions. This finding is particularly striking because if warned participants suspected that a critical word had merely been suggested, it would have always been correct to identify and to omit this word during free recall (i.e., critical words were never used as studied items in the present study). In this light, the present results extend recent work by Neuschatz et al. (2003) demonstrating that some DRM associative lists are more likely than others to have their corresponding critical words (a) identified by forewarned participants and (b) subsequently omitted from a recall or recognition memory test. Similarly, the results of the present study suggest that some young adults (high spans) are more likely than others (low spans) to benefit from experimenter-provided warnings prior to encoding, thereby reducing their susceptibility to false memories in the DRM paradigm. Indeed, low spans did not use warnings administered at encoding to reduce false recall in Experiment 2, in which the critical words were never presented but considered moderate to highly identifiable on the basis of normative data on these DRM materials published by Neuschatz et al.

Individual Differences, Repeated Study–Test Trials, and False Memories in the DRM Paradigm

Using a multiple study–test trial procedure in conjunction with the DRM paradigm, McDermott (1996) was the first to demonstrate that veridical memory increased across repeated study–test trials, whereas false memory decreased (see Budson et al., 2000; Kensinger & Schacter, 1999; Watson et al., 2004, for replications and extensions). Within an activation-monitoring framework (Balota et al., 1999), young adults may use repeated study–test trials to verify what is presented and to determine what is strongly associated but not presented, gradually improving their veridical memory while concurrently diminishing (but not eliminating) their false memory with practice. More important for the purposes of the present article, as shown in Figure 2, both high and low span young adults used repeated study–test trials to reduce but not eliminate their recall of nonpresented critical words in the DRM paradigm.

Therefore, the present study yielded a dissociation in which low span young adults benefited from practice but not warnings designed to reduce false memories in the DRM paradigm. In contrast, high span young adults benefited from both manipulations and greatly reduced their recall of nonpresented critical words when these two types of monitoring manipulations were combined (see Watson et al., 2004, for a similar study comparing the differential effectiveness of warnings and repeated study–test trials in young and older adults). Furthermore, with respect to using the results of Experiment 2 to rule out a retrieval-monitoring account of the results of Experiment 1, as shown in Figure 2, although the high spans recalled slightly more studied words than the low spans in the warning condition across study–test trials, the high spans evidently did not use their increasing veridical memory advantage across trials to modulate the influence of the warning manipulation and further reduce their probability of false recall. That is, in contrast to the findings in veridical recall, there was no three-way interaction of span, warning, and study–test trial for the recall of nonpresented critical words in Experiment 2.

From an attentional-control perspective, repeated study–test trials may rely on a different underlying mechanism than warnings to successfully reduce susceptibility to associative false memories in the DRM paradigm (Watson et al., 2004). Briefly, the idea is that practice provides multiple chances to learn the associative lists, giving participants the opportunity to discount the perceptual support for critical words provided by their own output at test in favor of the perceptual information that can be gleaned from additional study episodes. In this light, the results of the present study suggest that individual differences in WMC do not influence young adults' ability to spontaneously use repeated study–test trials to monitor their own memory performance at retrieval to reduce false recall in the DRM paradigm. However, consistent with the individual differences and WMC literature (see Kane & Engle, 2002, for a review), as expected, the results of the present study clearly demonstrated (a) breakdowns for low span young adults in the active maintenance of task goals, as evidenced by (b) the inability of low spans to use experimenter-provided warning instructions administered at encoding to reduce false memories for nonpresented critical words elicited by the DRM paradigm.

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