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The Deese-Roediger-McDermott (DRM) task: a simple cognitive paradigm to investigate false memories in the laboratory

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Abstract:	The DRM task is a false memory paradigm in which subjects are presented with lists of semantically related words (e.g., nurse, hospital, etc.) at encoding. After a delay, subjects are asked to recall or recognize these words. In the recognition memory version of the task, subjects are asked whether they remember previously presented words, as well as related (but never presented) critical lure words ('doctor'). Typically, the critical word is recognized with high probability and confidence. This false memory effect has been robustly demonstrated across short (e.g., immediate, 20 min) and long (e.g., 1, 7, 60 days) delays between encoding and memory testing. A strength of using this task to study false memory is its simplicity and short duration. If encoding and retrieval components of the task occur in the same session, the entire task can take as little as 2-30 min. However, although the DRM task is widely considered a 'false memory' paradigm, some researchers consider DRM illusions to be based on the activation of semantic memory networks in the brain, and argue that such semantic gist-based false memory errors may actually be useful in some scenarios (e.g. remembering the forest for the trees; remembering that a word list was about "doctors", even though the actual word "doctor" was never presented for study). Remembering the gist of experience (instead of or along with individual details) is arguably an adaptive process and this task has provided a great deal of knowledge about the constructive, adaptive nature of memory. Therefore, researchers should use caution when discussing the overall reach and implications of their experiments when using this task to study 'false memory', as DRM memory errors may not adequately reflect false memories in the real world, such as false memory in eyewitness testimony, or false memories of sexual abuse.
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TITLE:
The Deese-Roediger-McDermott (DRM) task: a simple cognitive paradigm to investigate false memories in the laboratory

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SHORT ABSTRACT:
Here we present the DRM task, a tool to study false memories in the laboratory. Subjects study lists of semantically related words (nurse, sick, etc.), and later falsely remember an unstudied word (doctor) that represents the gist, or theme, of the word list.

LONG ABSTRACT:
The DRM task is a false memory paradigm in which subjects are presented with lists of semantically related words (e.g., nurse, hospital, etc.) at encoding. After a delay, subjects are asked to recall or recognize these words. In the recognition memory version of the task, subjects are asked whether they remember previously presented words, as well as related (but never presented) critical lure words ('doctor'). Typically, the critical word is recognized with high probability and confidence. This false memory effect has been robustly demonstrated across short (e.g., immediate, 20 min) and long (e.g., 1, 7, 60 days) delays between encoding and memory testing. A strength of using this task to study false memory is its simplicity and short duration. If encoding and retrieval components of the task occur in the same session, the entire task can take as little as 2-30 min. However, although the DRM task is widely considered a 'false memory' paradigm, some researchers consider DRM illusions to be based on the activation of semantic memory networks in the brain, and argue that such semantic gist-based false memory errors may actually be useful in some scenarios (e.g. remembering the forest for

the trees; remembering that a word list was about “doctors”, even though the actual word “doctor” was never presented for study). Remembering the gist of experience (instead of or along with individual details) is arguably an adaptive process and this task has provided a great deal of knowledge about the constructive, adaptive nature of memory. Therefore, researchers should use caution when discussing the overall reach and implications of their experiments when using this task to study ‘false memory’, as DRM memory errors may not adequately reflect false memories in the real world, such as false memory in eyewitness testimony, or false memories of sexual abuse.

INTRODUCTION:

The Deese-Roediger and McDermott (DRM) task was initially created by Deese[1], and later revitalized by Roediger and McDermott[2] as a convenient means of studying false memory in the laboratory. Although some[3,4] argue it should be called the DRMRS task, for the contributions of Read[5] and Solso[6], the most common name in the literature is the DRM task, and we call it by that name here. After a seminal paper published by Roediger and McDermott[2], interest of false memory research skyrocketed (see [7]), resulting in over 2,800 citations of that article to date. According to Roediger and McDermott, they revived the experimental design created by Deese because there was no reliable laboratory paradigm to induce false recall, while evidence of false recognition (e.g., [8,9]) did “little to discourage the belief that more natural, coherent materials are needed to demonstrate powerful false memory effects”[2].

One such example of a “more natural” paradigm is the misinformation paradigm[10,11]. In this task, subjects are presented with a story through pictures, slides, or video. Later, misleading information is provided, and the question is whether subjects will incorporate this misleading information into their recollection of the story. The DRM task is simpler than the misinformation paradigm in several respects. DRM encoding requires only the quick presentation and learning of lists of words, either visually or aurally. Retrieval testing for the DRM task is equally convenient regardless of the particular method used. In a recognition test participants are presented with a subset of the encoded words, the critical lure words (e.g., ‘doctor’), and unrelated lure words and have to make simple judgments of whether they remember each word or not, whereas in a recall test, participants have to write down all the words they are able to remember. In contrast, free recall testing for the misinformation paradigm is impractical, as it requires time-consuming content analysis. Additionally, the DRM task does not require any manipulation between encoding and testing, as DRM ‘false memories’ are spontaneously self-generated. The misinformation errors, on the other hand, are induced via external suggestions. Although both the DRM and misinformation paradigms are argued to assess false memory, newer studies have found small ($r = 0.12$)[12] or no relationship[13,14] between the misinformation and the DRM effects, suggesting that different mechanisms may be at play for each type of false memory. Moreover, the DRM illusions are argued to be a byproduct of the constructive nature of memory [15], which can be considered an evolutionarily adaptive process[16].

The DRM false memory effect is highly robust across studies (for quantitative reviews see[17,18]), and there is considerable evidence that the DRM task is quite reliable[27] (but see[28]). The DRM false memory effect has been found using various delay intervals, including those as short as an immediate test, and those delaying memory testing until 60 days later[19–21] (but see [22]). Warning subjects of the DRM illusion reduces, but does not erase, the effect [14,23]. The DRM effect has also been found with different encoding strategies, such as changes in word presentation duration[24] , and can be increased by several post-encoding manipulations, such as sleep[25] or stress[26].

Moreover, the DRM task has been utilized by many laboratories to study false memory formation in a variety of subject populations, such as children[29–32] and older adults[33], and in a variety of research fields, including individual cognitive (e.g., working memory[28,34]) and personality differences[35], neuroimaging[36,37], and neuropsychology[38]. In spite of its popularity, however, many have argued against the generalizability of the DRM task, and whether the creation of DRM false memories is comparable to the naturalistic creation of false autobiographical memories outside of the laboratory, such as memories of child abuse recovered in psychotherapy[39–41]. Nonetheless, several studies have found that subjects that are more susceptible to DRM false memories are also more prone to autobiographical memory distortions[42], fantastic autobiographical memories (alien abductions[43]; past lives[44]), and recovered autobiographical memories[45].

In short, the DRM task has been a useful tool to investigate the neurocognitive underpinnings of the (re)constructive nature of memory[16,46], regardless of the ongoing debate about how appropriate and relevant it is in the study of autobiographical false memories[7]. In the current report, the DRM task procedures are explained in their simplest form, with a focus on targeting memory consolidation processes (i.e., experimental manipulations, such as sleep and stress, occur after encoding has finished and are thus used as tools to evaluate consolidation), as this has been the focus in our laboratory. The authors refer the reader to Gallo (2013)[47] for an excellent review of the DRM task, along with the different variations on encoding and testing procedures.

PROTOCOL:

The Institutional Review Board of the University of Notre Dame approved all of the procedures, including use of human subjects, discussed here. The preparation and the administration of the DRM task materials described below were used in a published study[26], in which the effects of psychosocial stress following DRM word list encoding were assessed 24 h later.

1. Preparation of DRM task

1.1. Use the word lists from Stadler, Roediger, and McDermott[48], presented in the Appendix, to select the appropriate number of word lists for the experiment. From Tables 1 and 2, select the word lists with the highest probability of false recall and recognition. The more word lists used in the experiment, the greater the number of false words participants will have a chance to remember.

Note: Tables 1 and 2 show the probability of false free recall and recognition memory, respectively, of the top 18 word lists used by Stadler et al[41]. The Appendix presents the complete word lists. See also Gallo and Roediger[49] for additional normed word lists.

1.2. Prepare the encoding task

1.2.1. Choose modality of presentation of word lists. See Discussion for issues regarding the selection of presentation modality.

Note: Presentation modality can be either visual or auditory.

1.2.2. If auditory presentation is chosen, digitally record all the words in each list. Use professional-grade equipment (e.g., Rode NT1-A microphone), preferably an unfamiliar voice and a soundproof or sound-resistant room.

1.2.3. Record the word lists in descending strength of association, as they are presented in the Appendix, at a rate of one word every two seconds.

1.2.4. At the end of each list, include a reasonably long delay (e.g., 12 s) of silence, followed by a 1-s tone, 2 s of silence and then the start of the next list. This helps participants parse the individual lists.

1.2.5. Use a audio-editing software (e.g., Audacity) to apply these standards.

1.2.5.1. Drag and drop the audio file into the audio-editing software.

1.2.5.2. Use the mouse cursor to select the portion of audio to which silence will be applied.

1.2.5.3. On the top, select Edit>Remove Audio>Silence Audio.

1.2.5.4. To apply the 1-s tone at the start of each list, use the copy and paste options in the audio-editing software.

1.2.5.5. To save the recording, press STOP, select File>Export, and choose file format and destination of the audio file.

1.3. Prepare the testing task

1.3.1. Choose a retention interval between encoding and testing that is appropriate for the experiment. If addressing the effects of stress on memory performance, choose at least 24 h.

1.3.2. **For the free recall task**, have a blank piece of paper or a blank document in a word-processing application (e.g., MS Word) ready.

1.3.3. **For the recognition task,** select words to include in recognition task.

1.3.3.1. Include study words (i.e., words presented at encoding) from positions 1, 8, and 10 from each list included in the encoding task[2]. See Appendix for complete word lists.

1.3.3.2. Include all critical lure words (i.e., false words not presented at encoding that represent the gist of the word list) from each list included in the encoding task. See Appendix for complete word lists and their appropriate critical lure.

1.3.3.3. Include the same number of additional, non-presented words (i.e. foil words that are unrelated to any of the studied DRM lists), from other, non-studied DRM word lists, from the same positions (1, 8, and 10) and their corresponding critical lures.

Note: For example, if 15 DRM word lists are presented during encoding, for the recognition test, present 120 words: 45 study words, 15 critical lure words, 45 non-presented list items from other non-studied DRM word lists, and 15 critical words from those non-studied DRM word lists.

1.3.4. Use experiment creation software (e.g., E-Prime) to create self-paced presentation of the words and to achieve data collection.

1.3.4.1. Use black font with a white background, and reasonable font size, depending on screen size/resolution.

1.3.4.2. In a standard old/new recognition test, use separate keys to assign responses; such as the 'Z' key for old and the 'M' key for new. If possible, add this legend in with the presentation of each word on the screen. Software such as E-Prime will automatically collect reaction times and key responses.

2. Administration of DRM task

2.1. **Administration of encoding task**

2.1.1. Ask subject to sit in front of device containing the recording of the word lists. Ensure subject is comfortable.

2.1.2. Read the following instructions to the subjects: "For this cognitive task you will be listening to lists of words. At the final word of each list, there will be a 12 second break, followed by a one second tone, followed by two seconds of silence, and then the start of the next list. Please pay close attention to the words because you will be tested on them at the next session."

2.1.3. Ask subject to put on headphones. To ensure participants have no distractions, turn off the computer monitor. Press play.

2.1.4. Inform participant that this session has ended and provide them with instructions for the next (testing) session.

2.2. **Administration of testing task**

2.2.1. **Free recall test**

2.2.1.1. Ask subject to sit down in front of a table or desk (if using pen and paper) or in front of the computer (if using a word processing blank document).

2.2.1.2. Read the following instructions to the subject: "This part of the task involves a simple memory test. Please write down all the words you can remember from the lists you heard in the last session. You have 10 minutes to recall all the words you can. When there are 2 minutes left, I will let you know. Any questions?"

2.2.1.3. Answer any questions the subject may have.

2.2.1.4. Start the timer and inform subject of the two-minute warning mark.

2.2.1.5. Stop subject after time is up.

2.2.2. **Recognition test in the computer**

2.2.2.1. Open recognition test with the experiment creation software.

2.2.2.2. Ask subject to sit in front of computer.

2.2.2.3. Read the following instructions to the subject: "This is a simple recognition task. You will see a word on the screen. Use the keyboard to answer whether each word is old (that is, on one of the lists you heard/saw previously) or new. You will use the 'Z' key if you think the word is old and the 'M' key if you think the word is new. This is self-paced, but we are also measuring your reaction time, so answer as quickly but accurately as you can. Let me know you are done. Any questions? ".

2.2.2.4. Answer any questions the subject may have.

2.2.2.5. Start the recognition test and wait for the subject to finish.

2.2.3. Debrief the subject and thank them for their participation in the study.

REPRESENTATIVE RESULTS:

Using the procedure presented here, the authors have been able to reliably produce the DRM effect in two independent experiments; that is, subjects recall and recognize, with high probability, non-presented critical words that can be considered false memories for the 'gist' of the word lists.

Results for experiment 1 (see Figures 1 and 2) have been published elsewhere[26]. In that experiment, 67 subjects arrived at the laboratory, listened (through headphones) to 15 DRM word lists and then were submitted to a psychosocial stress task involving public speaking (Trier Social Stress Test) or a control version of the task. Subjects returned 24 h later to complete the free recall test, immediately followed by the recognition test, as described above. Of relevance to the current report, the overall proportion of words recalled and recognized was higher for critical words (false recall M=0.20, false recognition M=0.71) than for presented words (true recall M=0.09, true recognition M=0.65), t(66)=8.61, p<.001, Cohen's d=1.22 for recall [Figure 1]; t(66)=2.42, p=0.02, Cohen's d=0.29 for recognition [Figure 2]). Importantly, recognition of critical words was also significantly higher than recognition for unrelated foil words (M=0.36), t(66)=12.88, p<.001, Cohen's d=1.57.

[Insert Figure 1 and Figure 2 here]

Similar results were obtained in experiment 2 (unpublished data; see Figures 3 and 4). In that study, 117 subjects encoded 16 DRM word lists either at night, before going to sleep, or during the morning, prior to a period of wakefulness. Subjects returned 24 or 48 h later to complete the free recall test followed by the recognition test. The overall proportion of words recalled and recognized was higher for critical words (false recall M=0.20, false recognition M=0.72) than for presented words (true recall M=0.09, true recognition M=0.65), t(116)=12.4, p<.001, Cohen's d=1.36 for recall [Figure 3]; t(116)=3.66, p<.001, Cohen's d=0.39 for recognition [Figure 4]). Importantly, recognition of critical words was also significantly higher than recognition for unrelated foil words (M=0.37), t(116)=15.68, p<.001, Cohen's d=1.44.

[Insert Figure 3 and Figure 4 here]

The fact that, in these two independent studies conducted in our laboratory, false memories (critical words) were remembered proportionally more often than true memories (studied words) 24 and 48 h after encoding is consistent with early studies that showed a similar false memory persistence effect over long delays[19–21]. These results underscore the efficacy of the DRM task in eliciting false memories across lengthy delay intervals, at least as false memories can be broadly defined as remembered events that were not actually experienced by the subject.

Table 1: Probability of false recall ranked from highest to lowest according to Stadler et al., 1999[41].

Stadler and colleagues[41] found that the lists associated with these critical words have the highest probability of producing a false memory in a free recall test. Presented here are the critical words only (i.e., the non-presented word that is falsely remembered at retrieval testing). See the Appendix for each complete list.

Table 2: Probability of false recognition ranked from highest to lowest according to Stadler et al., 1999[41].

Stadler and colleagues[41] found that the lists associated with these critical lure words have the highest probability of producing a false memory in an old/new recognition test. Presented here are the critical lures only (i.e., the non-presented word that is falsely remembered at retrieval testing). See the Appendix for each complete list.

Figure 1: Recall rates from experiment 1 (Pardilla-Delgado et al., 2016)[20].
Bars represent means and error bars represent standard error of the mean. Relevant to this report, the overall memory for false recall (last two bars) is significantly higher than memory for true recall and recognition.
*** p<.001

Figure 2: Recognition rates from experiment 1 (Pardilla-Delgado et al., 2016)[20].
Bars represent means and error bars represent standard error of the mean. Relevant to this report, the overall memory for false recognition is significantly higher than memory for true and foil recognition (last three bars).
* p<.05
*** p<.001

Figure 3: Recall rates from experiment 2.
Bars represent means and error bars represent standard error of the mean. Groups: S24: Sleep 1st/24 h delay, W24: Wake 1st/24 h delay, S48: Sleep 1st/ 48 h delay, W48: Wake 1st/48 h delay. Relevant to this report, the overall memory for false recall (last two bars) is significantly higher than memory for true recall.
*** p<.001

Figure 4: Recognition rates from experiment 2.
Bars represent means and error bars represent standard error of the mean. Groups: S24: Sleep 1st/24 h delay, W24: Wake 1st/24 h delay, S48: Sleep 1st/ 48 h delay, W48: Wake 1st/48 h delay. Relevant to this report, the overall memory for false recognition (last three bars) is significantly higher than memory for true and foil recognition.
*** p<.001

Appendix: Critical words (in alphabetical order) with list items (ranked by associative strength) for top 18 lists for free recall.
Bold words at top represent the 'gist' of the list and are considered the critical words (false memories); these words are not presented at encoding.

DISCUSSION:

In this report, the authors described a highly used cognitive task that reliably produces gist-based false memories in human subjects. It is important to note that, in the current report, the DRM task was presented in one of its simplest forms, very similar to the original protocol used by Deese[1] and Roediger and McDermott[2]. The similarity with the original protocol used in the experiments described here has one particular exception: a long delay (24, 48 h) between encoding and testing, which is useful when testing the persistence of false memories over true memories[20] or following manipulations that can affect memory consolidation, such as sleep[25] and stress[26]. Related to this issue, in the current experiments, the recognition test was administered immediately after the free recall test, which has been found to increase recognition rates[2,18]; therefore, we caution the reader to interpret our recognition data accordingly. Additionally, although several early [2] studies, as well as the presented studies suggest that critical words (false memories) are consistently remembered better than study words (true memories), others have shown the opposite pattern, particularly for short term memory tests[17,18].

The DRM task has multiple modifications (for review, see[39]), ranging from, but not limited to: 1) changes to encoding processing, such as warnings about the effect[23], relational and associative processing instructions[45,46], priming[47], incidental encoding[48], and rapid word presentation[49]; 2) changes to the testing method, such as forced-choice tests[50], speeded recognition tests[51], and recollection vs. familiarity judgments[2]; and 3) changes to critical word features, such as using taboo words[52], long words[53], and concrete words[54].

There are several important factors researchers should consider when using the DRM paradigm. Here, we recommend using the work from Stadler et al. (1999)[40] in order to choose the word lists to be presented at encoding. In the study by Stadler and colleagues, subjects recalled each list immediately after listening to the words, whereas the recognition test was given after all lists had been presented and recalled. Therefore, recall and recognition rates may vary if longer retention intervals are used, as we have done in our laboratory. Our mean false recall rates were M=0.20. Across shorter delays, like those used by Stadler et al.[48]mean false recall rates can be higher (e.g., M=0.51 for the top 18 lists[48]). Further, we recommend using auditory presentation, as it is the more common of the two modalities (visual or auditory). Visual presentation has also been shown to decrease the DRM effect[50,51]. Depending on the experimental question and if a more detailed assessment of memory is desired, individual confidence ratings can be added at testing, to both recall and recognition tasks. For the recognition test, “remember” and “know” judgments[52] can alternatively be used. In our studies, participants were given 10 minutes for the recall task to allow them to retrieve as many words as possible, because 1) 180 words were presented at encoding (15 lists/12 words per list) and 2) there were 24-48 h intervals between encoding and testing, which was bound to reduce retention. Regarding statistical analysis, although in the current report we presented uncorrected recognition rates (for simplicity), the reader might consider signal detection methods to analyze the recognition test data[53] (see Seamon et al.[21] for a good example of signal detection methods with the DRM task). Regarding tools and materials, in the event that experiment creation software is not available, word presentation for the recognition test can also be done using slideshow creation software (e.g., PowerPoint), while having subjects answer old/new on a sheet of paper.

One particularly important factor to keep in mind for future experiments is that increasing the number of semantically related words in each list boosts the false memory effect[55], i.e., in order to increase the probability of false recall/recognition, it is paramount that experimenters present as many words as possible (for each list) during encoding; see Appendix for the complete word lists. Similarly, using an insufficient number of word lists may also decrease the ability to observe a clear effect, especially regarding correlations (i.e., statistically significant correlations are more difficult to observe when the range of a variable is small, as would be the case if few DRM word lists were included in a study[25]). In contrast, this is opposite to the suggestion of, if using recognition as the testing method, not including some of the list items at encoding in order to use them as non-presented foils during recognition testing. Related to this, it is suggested to include critical lures from non-studied DRM word lists in the to-be-recognized words[18], because DRM critical lures have higher word frequencies and higher baseline false alarm rates than study (list) items[2,56]. This is one procedure that represents a high-threshold correction that addresses response bias. Another possible procedure is using signal detection methods (see Seamon et al.[21]).

The DRM is not without its limitations. Some have argued that the simple gist-based errors caused by the DRM task are related to spreading activation in semantic memory networks in the brain and may not be comparable to false autobiographical memories, such as the "recovered" memories of child abuse resulting from psychotherapy[41]. Although addressing this decade-long question is outside the scope of this report, the authors agree with Gallo in that "the appropriate questions to ask are what aspects of the DRM illusion are relevant to what aspects of autobiographical memories" (p. 834)[7]. Related to this dilemma, using the original DRM task, as described in the current report, can result in ambiguous interpretations because there are several activation/monitoring processes that govern this type of gist-based false memory formation[57]. Broadly speaking, future applications of the DRM task should continue addressing the reconstructive nature of memory, and more specifically, the transformation of single episodes into generalizable, flexible, and useful gist abstractions. Regardless of the research question, caution is always warranted when generalizing the results of studies using the DRM false memory task to other, real-world, forms of false memory, as the DRM task is a humble cognitive paradigm, yet one with great research potential.

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The authors have nothing to disclose.

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Figure 1

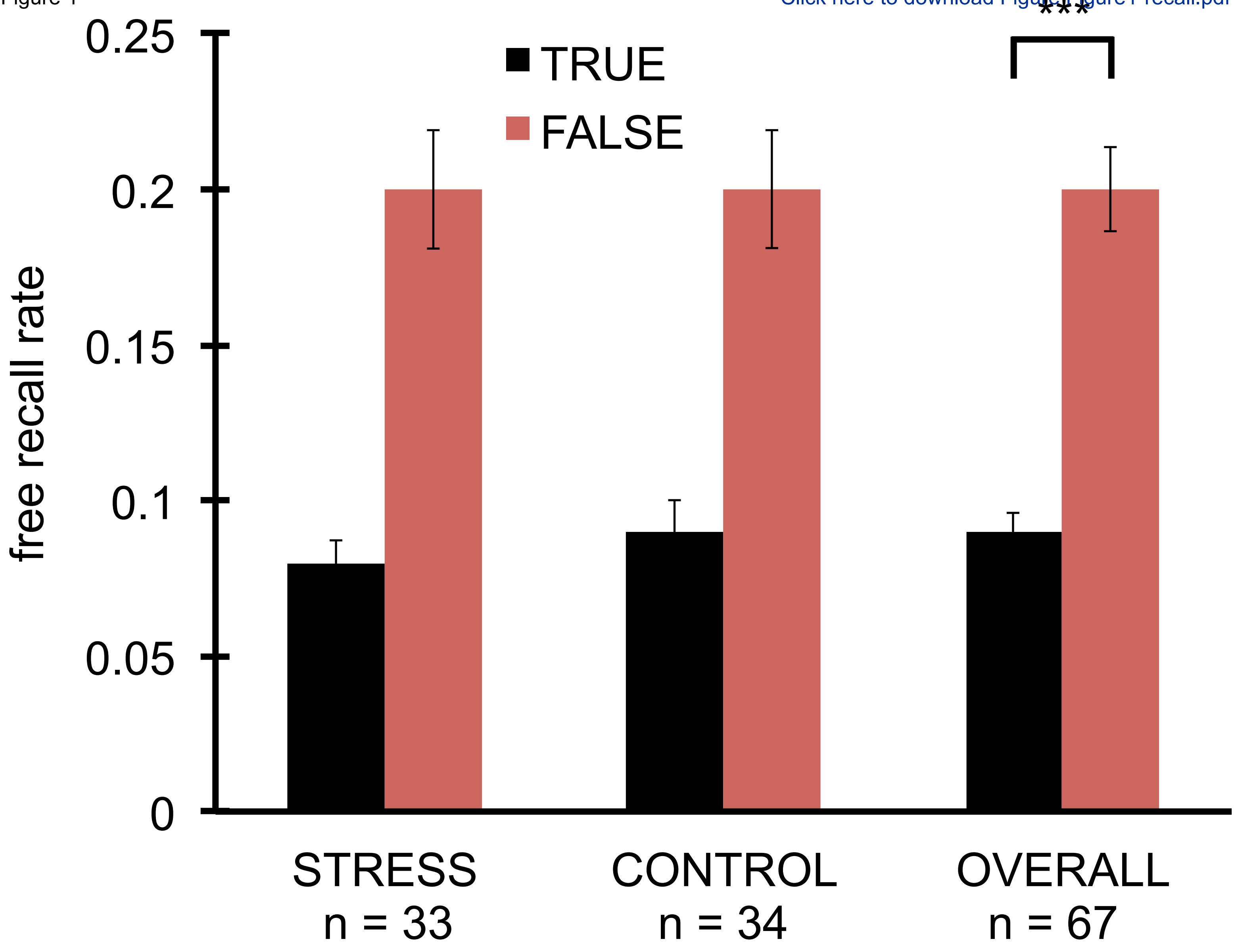
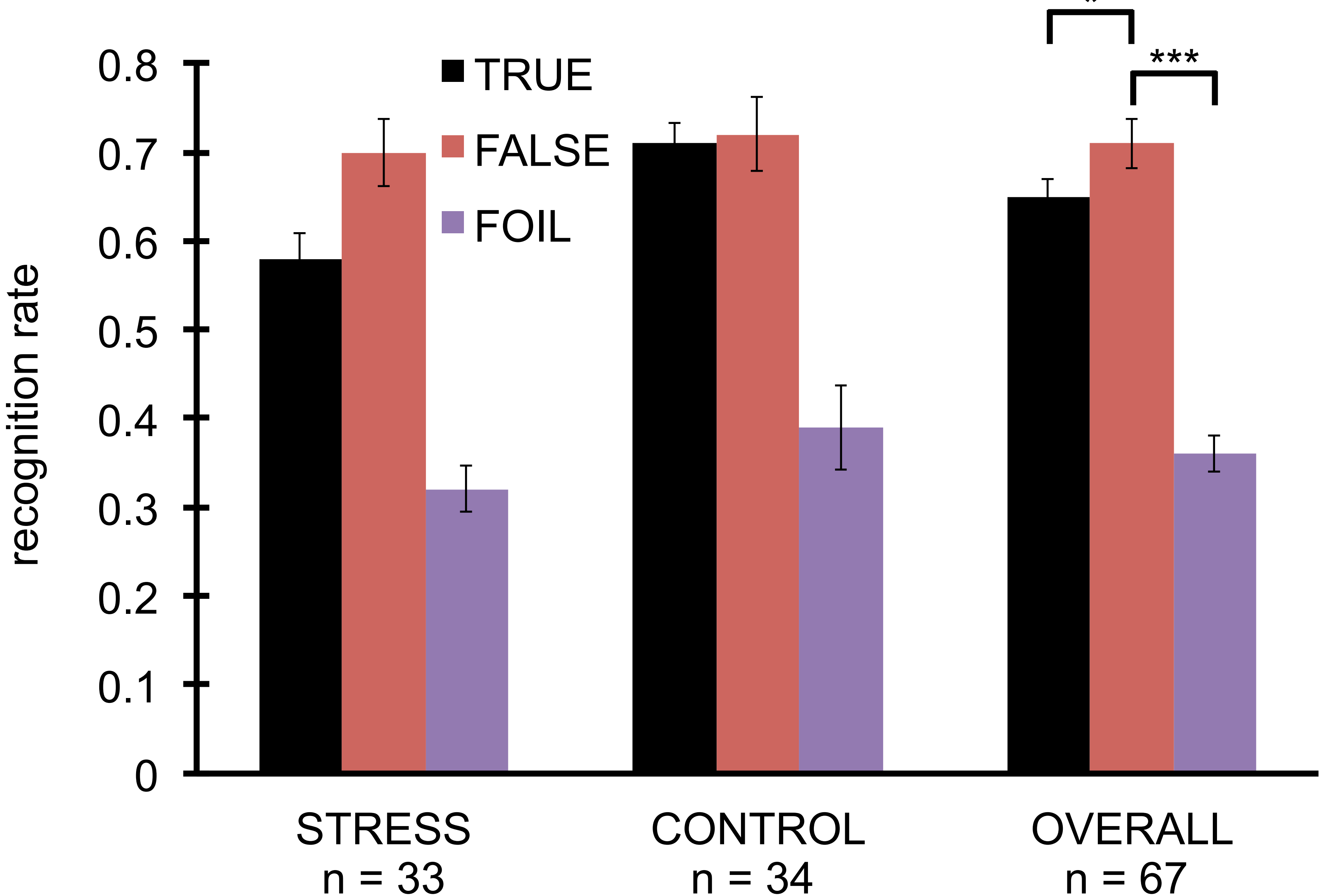

***
TRUE
FALSE
0.25
0.2
0.15
0.1
0.05
0
free recall rate
STRESS
n = 33
CONTROL
n = 34
OVERALL
n = 67

Figure 2



*
***
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
recognition rate
TRUE
FALSE
FOIL
STRESS
n = 33
CONTROL
n = 34
OVERALL
n = 67

Figure 3

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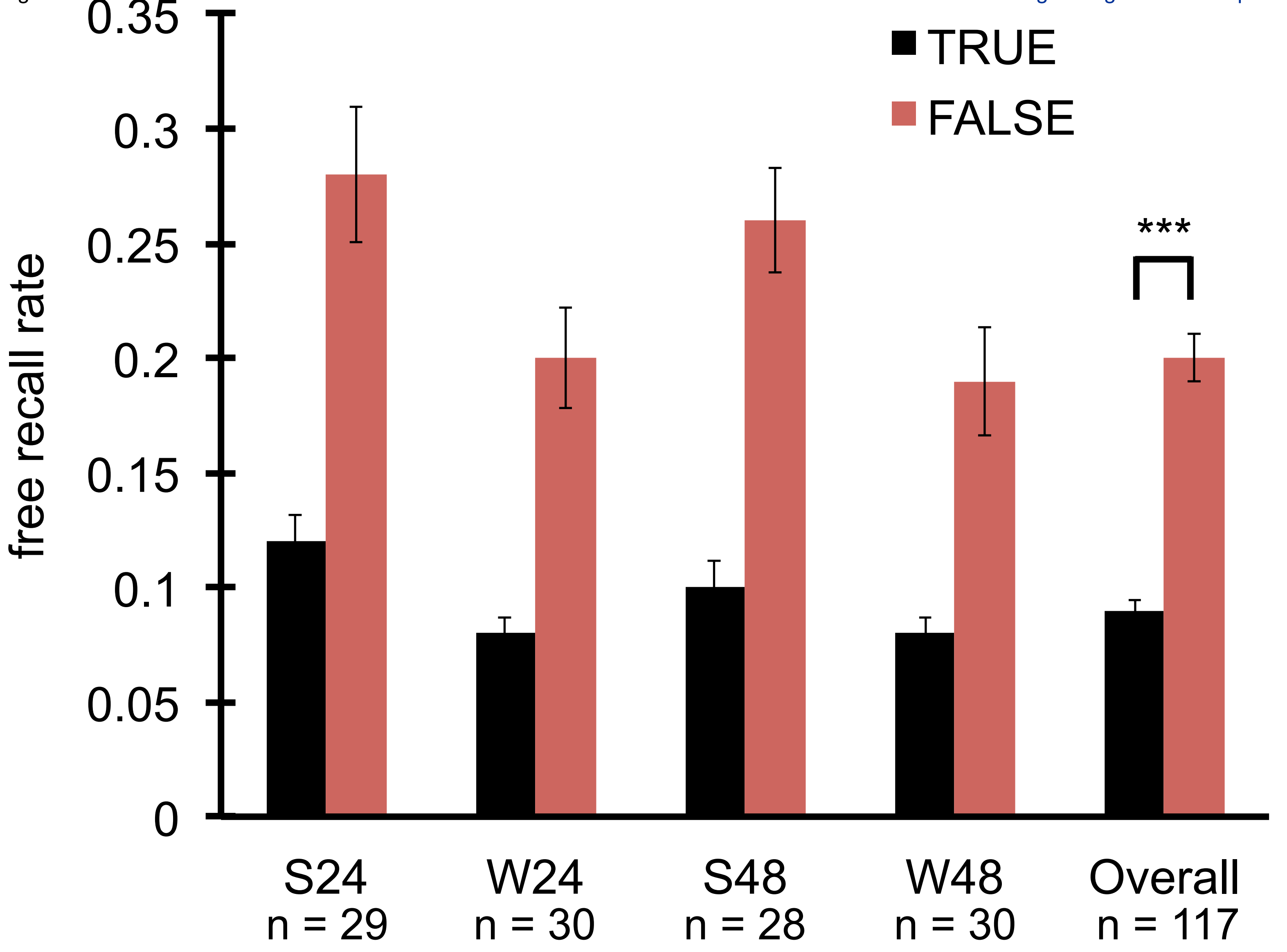

Figure 4

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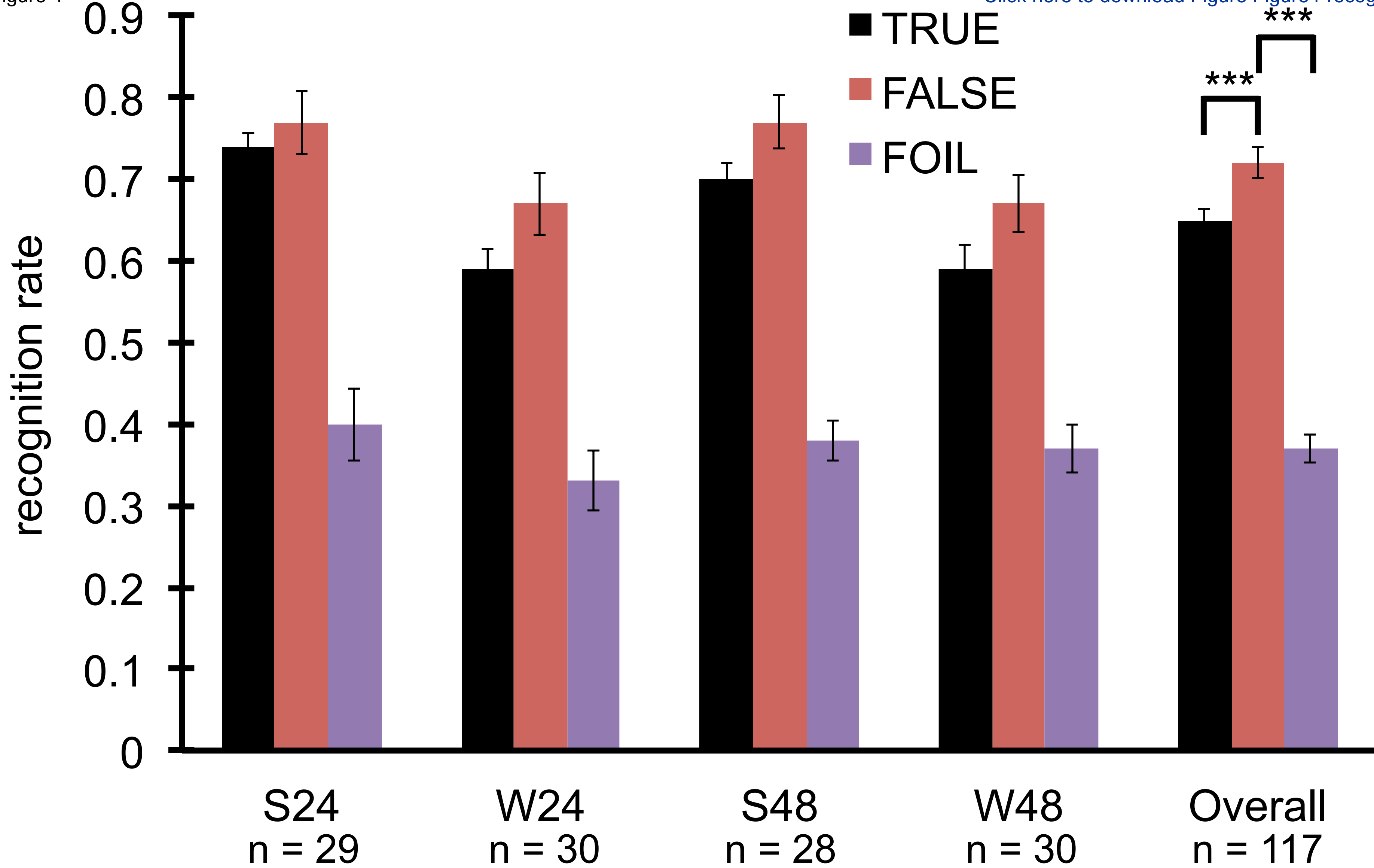

Probability of false recall ranked from highest to lowest according to Stadler et al., 1999	
WINDOW	65
SLEEP	61
SMELL	60
DOCTOR	60
SWEET	54
CHAIR	54
SMOKE	54
ROUGH	53
NEEDLE	52
ANGER	49
TRASH	49
SOFT	46
CITY	46
CUP	45
COLD	42
MOUNTAIN	42
SLOW	42
RIVER	51

Probability of false recognition ranked from highest to lowest according to Stadler et al., 1999	
WINDOW	84
SMELL	84
COLD	84
ROUGH	83
CUP	82
SOFT	81
SLEEP	80
ANGER	79
SWEET	78
TRASH	78
CHAIR	74
SMOKE	73
HIGH	72
DOCTOR	71
THIEF	70
MOUNTAIN	69
SLOW	69
MUSIC	69

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Audacity	Audacity	http://www.audacityteam.org/	for editing the recording of the wordl
E-Prime	Psychology Software Tools, Inc.	https://www.pstnet.com/eprime.cfm	for stimuli presentation and/or testin
MS PowerPoint (optional)	Microsoft		for stimuli presentation and/or testin
MS Word (optional)	Microsoft		for free recall testing. Any word proce

:he wordlists

ists

g
g
:ssor application will work.

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Author(s): Enmanuelle Pardilla-Delgado and Jessica D. Payne

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Editorial comments:
1. Formatting:
-Long abstract exceeds 300 words and must be shortened.

Response: Long abstract has been shortened.

-Please split 1.3.4 into two steps.

Response: Step 1.3.4 has been split into three steps.

-Please include spaces between all numbers and units.

Response: All numbers and units have a space between them.

-Please use superscript numbers for reference citations, including those in figure legends/tables.

Response: All in-text references are now accompanied by their reference superscript number.

2. Results:
-An appendix/supplemental material has not been provided as described.

Response: We apologize; it has been uploaded as an Excel file.

-Please provide a graphical representation of the data if possible, to provide visual interest for the video.

Response: Tables 3 and 4 have been substituted by graphs (Figures 1-4).

3. Discussion: Please discuss the future applications of the protocol.

*Response: Because of the broad spectrum of research that the DRM task can be applied to, the authors have decided to include a sentence (line 463) that reflects the comprehensive nature of the DRM task: "*Broadly speaking, future applications of the DRM task should continue addressing the reconstructive nature of memory, and more specifically, the transformation of single episodes into generalizable, flexible, and useful gist abstractions."

Reviewers' comments:

General response to R1: *The authors appreciate all the constructive feedback given by this reviewer. It has undoubtedly made the manuscript a more complete piece of work.*

Reviewer #1:
Manuscript Summary:
The authors provide instruction for the DRM paradigm. They recommend taking word lists from Stadler, Roediger, and McDermott (1999), presenting each list aurally at a pace of two

seconds per word, and leaving delays between each word list. They provide instructions on how to measure true and false memory with recall and recognition, and they recommend that these be measured at least 24 hours after the presentation of the word lists if stress is a variable in the study. The authors present data using these methods that show robust false memories for the critical lures. Finally, the authors discuss deviations to this protocol and mention the debate about whether DRM errors are actually false memories. We believe the authors have adequately described this method of eliciting false memories and explained how researchers may deviate from some of their recommendations. All of the major steps are described in sufficient detail for a novice researcher to understand how to use the DRM procedure. Their results are reasonable and we imagine others would get similar results if they were to follow the instructions in the manuscript.

Major Concerns: We have not major concerns.

Minor Concerns: We have just a few minor concerns and/or recommendations.
1) The Stadler et al. (1999) norms are not the most recent norms. The authors might consider mentioning more recent norms from Gallo and Roediger (2002; Variability among word lists in eliciting memory illusions: Evidence for associative activation and monitoring).

*Response: This reference has been added to the Protocol on line 153: "*See also Gallo and Roediger[49] for additional normed word lists."

2) In their presentation of representative results, the authors should include effect sizes with their t-tests. These effect sizes will be useful for subsequent researchers' power analyses.

Response: Effect sizes (Cohen's d) have been added to each statistical test in the Results section.

3) The authors should address the reliability of the DRM paradigm. Some studies have found it to be fairly reliable (e.g., Blair, Lenton, & Hastie, 2002, the reliability of the DRM paradigm as a measure of individual differences in false memories) whereas others have found low internal consistency (Lovden, 2003, The episodic memory and inhibition accounts of age-related increases in false memories: A consistency check).

*Response: This information has been added to the Introduction (line 94, see also references 17 and 18): "…*and there is considerable evidence that the DRM task is quite reliable[27] (but see[28])."

4) Finally, it might be useful to describe how to conduct signal detection analyses using recognition data. Signal detection analyses are becoming increasingly popular with the recognition tests of the DRM paradigm (e.g., in the articles cited as 8, 9, and 10 in the references). I don't think this is absolutely necessary but it could make a nice addition to the present version of the manuscript. It may be beyond the scope of this manuscript, so perhaps the authors can mention signal detection analyses and cite an article that explains how to do them.

*Response: This information has been added to the Discussion (line 429): "*Regarding statistical analysis, although in the current report we presented uncorrected recognition rates (for simplicity), the reader might consider signal detection methods to analyze the recognition test data[53] (see Seamon et al.[21] for a good example of signal detection methods with the DRM task)."

Additional Comments to Authors: None.

Reviewer #2:

General response to R2: *The authors appreciate all the attention given to the manuscript and all the constructive comments. The manuscript has definitely increased in quality because of their helpful critique.*

Manuscript Summary:

In this article, the authors describe the Deese-Roediger-McDermott (DRM) false memory task and provide a "user's manual" to conduct the task in the laboratory. We note several minor concerns below that we feel should be addressed. If they are addressed, we recommend publication.

Major Concerns: N/A

Minor Concerns:

1. The procedure outlined in the current paper calls for a 24 or 48-hour delay between the study and test phases. The authors should point out that these lengthy delays are rather uncommon. We realize that the authors are interested in false memory effects after sleep or after administration of a stressor task, in which memory consolidation is the primary focus. However, the results of the two experiments reported in the paper show critical lure false recall rates of 20%. This compares to the results of Stadler et al. (1999) who reported an average false recall rate of 51% across the top 18 DRM lists (p. 496). We assume that the differences between the results in the current paper and those of Stadler et al. stem primarily from the extended delay (i.e., after 24 or 48 hours, participants may not remember the list themes they studied, so they won't falsely recall the critical lures). Therefore, if readers of this article want to use this procedure to study false memory, it might be preferable to shorten the study/test delay so that false recall is greater than 20%.

*Response: This information has been added to the Discussion (line 418): "*Our mean false recall rates were M=.20. Across shorter delays, like those used by Stadler et al.[48]mean false recall rates can be higher (e.g., M=.51 for the top 18 lists[48])."

2. We wonder about the method of having a recall test followed by a recognition test. As pointed out by Gallo (Associative Illusions of Memory, 2006), prior testing of the lists often increases false recognition of the critical lures compared to when the lists are not tested. This introduces a potential confound that users of the procedure will need to be aware of.

*Response: This information has been added to the Discussion (line 370): "*Related to this issue, in the current experiments, the recognition test was administered immediately after the free recall test, which has been found to increase recognition rates[2,18]; therefore, we caution the reader to interpret our recognition data accordingly."

3. The authors stipulate that non-presented words (i.e., items from non-presented DRM lists and their corresponding critical lures) should be included on the recognition test. This is an important component of DRM recognition testing, but the authors might want to inform the reader that this part of the procedure represents a high-threshold correction that helps account for response bias. Although this is not important for the current paper, it is important to point out that this correction procedure is only one way to address response bias. Signal-detection methods may also be used.

*Response: This information has been added to the Discussion (line 450): "*This is one procedure that represents a high-threshold correction that addresses response bias. Another possible procedure is using signal detection methods (see Seamon et al.[21])."

Additional Comments to Authors: N/A

Reviewer #3:
General response to R3: *The authors are grateful to this reviewer for providing such concise and helpful comments. We believe by incorporating their comments we have made this article a better piece of science.*

Manuscript Summary:
The paper was well written. The DRM has been used in a variety of contexts and is fairly simple to conduct using the current research available. However, the method described would be helpful for researchers who wish to use the DRM (particularly the recognition portion) because all of the necessary information is condensed. Descriptions of time delays between word items and lists is useful as well as descriptions of high frequency word lists.

Major Concerns:
-The paper rational describes a more recent controversy over the generalization of the DRM. This seems to comprise a substantial portion of the introduction and Discussion but is irrelevant to the main purpose of the paper. This section should be removed and replaced by focusing more on the common uses of the DRM. If the section remains, then it should be mentioned that newer studies are comparing this paradigm to other false memory paradigms. Therefore, this methodology will ensure researchers who are making these comparisons are able to replicate. As a result, there will be less cause to believe that mixed findings from these new studies are due to variations in the methodology.

*Response: In line 87, in the Introduction we have changed the language to "*Although both the DRM and misinformation paradigms are argued to assess false memory, newer studies have found small ($r = .12$)[8] or no relationship[9,10] between the misinformation and the DRM effects, suggesting that different mechanisms may be at play for each type of false memory"
We understand this delivers the point of the reviewer, specifically, that it seems that the DRM task is different than other false memory tasks.

-The section regarding recognition was a bit unclear. More clarity on how many lures, actual items, and non-represented items would be helpful.

*Response: A note has been added to step 1.3.3.3 (line 208): "*Note: For example, if 15 DRM word lists are presented during encoding, for the recognition test, present 120 words: 45 study words, 15 critical lure words, 45 non-presented list items from other non-studied DRM word lists, and 15 critical words from those non-studied DRM word lists. "

Minor Concerns: There is a typo on line 233.

Response: The error has been fixed.

Additional Comments to Authors: N/A

Reviewer #4:
General response to R4: *The authors appreciate all the time and attention given to our manuscript and are thankful for the constructive feedback given by this reviewer. As explained more specifically below, we have chosen to apply some of the changes suggested by the reviewer while leaving some out of the final version. We understand the main idea of the current report is to present a brief, yet comprehensive introduction of the most popular DRM research, accompanied with easily accessible methodology to utilize the task. Therefore, we have decided not to discuss thoroughly the DRM(RS) literature.*

Manuscript Summary:
General
This paper contains a description of a paradigm for administering the "DRM" memory task. It is a useful contribution to methodology.

Specific
1. Abstract, line 12 (and elsewhere). Make "wordlists" two words.

Response: All "wordlists" have been changed to "word lists".

2. Although there are continuous line numbers, there are no page numbers. I like to have page numbers for reference purposes. I have numbered the pages, with 1 on the page with Line 1.

Response: Page numbers have been added.

3. P. 2, par. 2, Introduction. Lines 56 to 58 contain a history of the DRM procedure. It is actually a little more complex. I think that the following information should be included. Two other researchers should be recognized in the history of the paradigm: Read, who worked on it independently of the others and Solso, who worked on a similar procedure (Bruce & Winograd, 1988, p. 622; McKelvie, 2001). It has even been suggested that the

paradigm be named the DRMRS procedure in recognition of the contributions or Read and Solso (McKelvie, 2001).

*Response: We appreciate the thoroughness but we believe it would be better to keep the history of the task as simple as possible because this is a methods-oriented journal. This manuscript specifically is completely based on the task (re)developed by Roediger and McDermott (1995). Further, from our reading and understanding of the literature, we believe that a vast majority of the field refers to it as the DRM task, and we would not want to confuse the non-expert reader by varying its name. Nonetheless, we have added the references provided (see line 63): "*Although some[3,4] argue it should be called the DRMRS task, for the contributions of Read[5] and Solso[6], the most common name in the literature is the DRM task, and we call it by that name here."

Commented [A1]: Change RTR to reflect this new language.

4. Lines 62, 63. Is the implication that more natural materials are not needed for recognition studies as much as had been assumed? In other words, is it being argued that the DRM (RS) paradigm provides a non-natural set of materials to demonstrate false memory effects? If this is the argument, it would be helpful to state it explicitly.

Response: We do not try to make any claims that the DRM materials are "non-natural". In lines 62-63 we are giving the reasoning of Roediger and McDermott (1995) for further developing Deese's task. Our intention was to inform the reader that there is some Discussion about the generalizability of the DRM task and whether DRM illusions are comparable to false memories "retrieved" during therapy.

5. Par. 3, lines 82-84. What exactly is the argument here? Is it meant to support the notion that the DRM(RS) false memory mechanism is simply different from the misinformation effect mechanism? Or is it being suggested that DRM(RS) illusion can be seen as illustrating another process that is interesting for reasons other than false memory? Please clarify exactly what the main point is.

Response: We do not think these are two independent points. In fact, the misinformation paradigm, being particularly different than the DRM task, we believe it may reflect different memory processes than the DRM task. We believe this is expressed fairly clearly in the second paragraph of the introduction.

6. P. 2, bottom. The DRM(RS) false memory effect is indeed robust, both for recall and for recognition. It might be useful to give summary statistics for the rates of correct recall, correct recognition, false recall and false recognition, which can be found in two reviews (McKelvie, 2003, 2004).

Response: We have added these references to the Introduction, see line 93: "The DRM false memory effect is highly robust across studies (**for quantitative reviews see[17,18]**)"

7. P. 3, par. 3, line 109. Perhaps say more about how memory consolidation has been demonstrated, either here or later when the author's results are presented.
Response: Language has been added to clarify what we meant by targeting memory consolidation, see line 127 in the Introduction: " In the current report, the DRM task

procedures are explained in their simplest form, with a focus on targeting memory consolidation processes **(i.e., experimental manipulations, such as stress and sleep, occur after encoding has finished**), as this has been the focus in our laboratory."

8. P. 4, Line 137. Should there be a protocol for visual presentation? This statement implies that both have equal value. However, later in the paper (line 333), it is auditory presentation is recommended.

Response: We presented the protocol as we have used it in our experiments, that is, using auditory presentation for the words. We added that statement in the protocol to inform the reader that visual presentation is also an option.

9. P. 5, Line 183. I think that the paradigm should include a set of words that serve as foils for the critical non-presented associates. Indeed, the authors recognize this (P. 9, lines 354-355). In fact, it has been done in many recognition memory experiments with the DRM(RS) paradigm. For a review of these studies, along with values for correct and false recognition adjusted for the false alarms, see McKelvie (2004).

Response: As the reviewer states, we have had included this in our Discussion (lines 450). We have added McKelvie (2004) as a reference, which should prove helpful for the reader.

10. P. 6, Line 253. The authors claims in this section that the results presented are representative. However, although the false memory effect in both recall and recognition is robust, it is unusual for the rate to be higher than the rates for correct recall and correct recognition. Although it is also implied (P. 7, lines 274-275) that this effect occurred in early research, I think that it should be observed that it is not typical. Evidence that correct recall and recognition are usually higher than false recall and recognition can be found here in McKelvie's (2003, 2004) reviews.

Response: We have added this information in the first paragraph of the Discussion, see line 401: "Additionally, although several early [2] studies, as well as the presented studies suggest that critical words (false memories) are consistently remembered better than study words (true memories), others have shown the opposite pattern, particularly for short term memory tests[17,18]."

11. Pp. 6-7, previous results. Report standardized effect sizes.

Response: Effect sizes (Cohen's d) have been added to each statistical test in the Results section.

12. It might also be suggested that it would be useful to have a protocol for testing recognition alone, without testing recall first. Recall has been shown to increase the subsequent recognition (McKelvie, 2004).

Response: We have added this information in the first paragraph of the Discussion, see line 370: "Related to this issue, in the current experiments, the recognition test was administered immediately after the free recall test, which has been found to increase recognition rates[2,18]; therefore, we caution the reader to interpret our recognition data accordingly"

13. P. 8, line 351. Say more about the correlations. What was correlated? Why exactly would a smaller number of lists have a particular impact on correlations?

*Response: Additional language has been added to clarify this in the 4th paragraph of the Discussion, see line 441: "*Similarly, using an insufficient number of word lists may also decrease the ability to observe a clear effect, especially regarding correlations **(i.e., statistically significant correlations are more difficult to observe when the range of a variable is small, as would be the case if few DRM word lists were included in a study[25])."**

References of papers mentioned above:

McKelvie, S. J. (2001). Effects of free and forced retrieval instructions on false recall and recognition. The Journal of General Psychology, 128(3), 261–278.

McKelvie, S. J. (2003). False recall with the DRMRS ("Drummers") procedure: a quantitative summary and review. Perceptual and Motor Skills, 97, 1011–1030.

McKelvie, S. J. (2004). False recognition with the Deese-Roediger-Reid- Solso procedure: A quantitative summary. Perceptual and Motor Skills, 98(3, Pt 2), 1387–2408.

Conclusion I think that this is a useful contribution. However, some changes should be made if it is to be published.

Major Concerns: Give more history. Build into the paradigm a set of words that serve as foils for false recognition.

Minor Concerns: See narrative summary above. Some points should be clarified.

Additional Comments to Authors: N/A

Click here to access/download
Supplemental code file (if applicable)
JoVe_Appendix.xlsx