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# Using a Classroom-Based Deese Roediger McDermott Paradigm to Assess the Effects of Imagery on False Memories

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**TITLE:**

Using a Classroom-Based Deese Roediger McDermott Paradigm to Assess the Effects of Imagery on False Memories

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**KEYWORDS:**

DRM paradigm, false memories, word lists, imagery, false recall, false recognition.

**SUMMARY:**

The method presented here induced false memories using lists of related words and also assessed the effects of imagery instructions on the recall and recognition of those false memories. This protocol details a modified version of the Deese Roediger McDermott (DRM) paradigm.

**ABSTRACT:**

Associated word list procedures can elicit false memories in predictable ways by inducing associative processing, thus making it harder to monitor the accuracy of memories. The purpose of the method presented here was to induce false memories using lists of either semantically or phonologically related words and to assess the effects of imagery instructions on the recall and recognition of those false memories. To do this, we used a modified version of the Deese Roediger McDermott (DRM) paradigm. We adapted word lists from previous DRM studies to suit imagery procedures and created an automated presentation to present the word lists in classroom settings. We then recruited undergraduate classes and instructed some of the classes to create mental images of the list words as they were being presented, while instructing the other classes to simply remember the words. The automated presentation presented word lists to participants, one word at a time, alternating between phonologically and semantically related lists. Participants used paper-pencil recall packets to immediately recall list items, complete a distractor activity, and take a subsequent final recognition test. Often, participants immediately recalled and later recognized words that were related to the list items but were not actually presented; these are known as critical lures and indicate a false memory. The protocol detailed here describes a four-step procedure—list presentation,

immediate recall, distractor phase, and final recognition—that can assess the effects of list type and imagery instruction within the DRM paradigm on memory. The automated nature of the list presentation provides the ability to systematically vary variables of interest, and the paper and pencil method of data collection affords an easily accessible method for collecting data in classroom settings. The protocol also offers options to modify the procedure to a more traditional DRM paradigm without imagery and/or list type manipulations. The use of this protocol can provide results relevant to both classroom learning and cognitive science principles.

**INTRODUCTION:**

Memory is malleable and fallible, and these days people realize the limitations of their own memory system. But how do memory errors arise? What mechanisms are responsible for errors in memory retrieval? We modified a widely used and highly cited laboratory-based procedure called the Deese Roediger McDermott paradigm (DRM)[1,2] to investigate the influence of different variables on memory errors. In traditional DRM procedures, participants are asked to learn lists of semantically related words (*e.g.,* table, couch, desk, lamp, pillow, stool, bench, rocker*)*. When later asked to recall and/or recognize the words from the lists, participants often report seeing words that were semantically related to the lists but not actually studied (*e.g.*, chair). False memories for these words, referred to as *critical lures*, can occur 55% - 80% of the time in standard procedures[2-3].

The Activation Monitoring Framework is often cited as a theoretical basis for memory errors that arise from the DRM paradigm. Specifically, DRM false memories are attributed to the dual processes of *activation* (*i.e.,* the tendency for pieces of information currently active in working memory to "spread" and also activate other, related pieces of information) and *monitoring (i.e.,* assessing the accuracy and/or source of something being remembered)[5,6]. The process of studying semantically related DRM lists causes activation to spread from the list words to the critical lure and thus activates the critical lure in working memory. The result is a false memory that may not be accurately monitored during later tasks.

The three-phase testing procedure inherent to the DRM paradigm allows cognitive psychologists to manipulate a number of variables during the process of encoding (study of the list items), retention (storage of the list items while completing a distractor task to disrupt working memory), or retrieval (a memory test), to better understand the specific processes that contribute to memory errors. Our procedure expands use of traditional DRM procedures to directly compare memory error rates for different types of content during encoding (*e.g.*, semantically related *versus* phonologically related)[9], test type during retrieval (*e.g.*, a recall task *versus* a recognition task)[10] and, perhaps most notably, imagery encoding processes during list study[11-14].

Our primary interest in developing this protocol was to better understand possible effects of imagery on recall and recognition, particularly whether the effects of creating mental images of the list words during encoding (*e.g.*, imagining them) would vary according to whether the list words were related to the critical lure according to sound (*i.e.,* phonologically) or meaning (*i.e.,* semantically). For instance, for the phonological list *log, hog, dock, bog, fog, doll, frog, jog,* and *dot*, the critical lure is *dog*. For the semantic list *mug, saucer, tea, coaster, lid, coffee, straw,* and *soup*, the critical lure is *cup*. We were interested in whether imaging the list words affected the associative processing for those lists differently. While traditional DRM word lists contain 12-15 semantically related list words[2], our procedure employed 8-item word lists. These lists were modified from 16-item lists previously developed to investigate the converging effects of phonological and semantic word associations on false memories[9]. In order to adapt typical DRM procedures to include imagery instructions, we shortened the word lists by selecting the 8 words from each list that were easiest to create mental images of. This allowed for the elimination of less concrete words (*e.g.*, pun, worst) that were hard to imagine. Additionally, we modified a computer-based word list presentation utilized in previous research[15] to standardize the presentation of materials and also developed paper/pencil recall and recognition measures to more appropriately suit classroom environments.

Our results did not suggest an interaction between list association type and imagery procedures, but they did demonstrate the significant main effects of imagery and list type[14]. We pursued this line of inquiry because of the robust literature of imagination inflation effects suggesting enhanced feelings of belief and memory in past childhood events that are repeatedly imagined[16-18]. However, recently researchers suggest that perhaps not all imagery is created equal and that the nature of imagery instructions mediates the effects on false memory rates[19]. One possible limitation to the work assessing imagination inflation effects is inherent in the procedure itself. That is, participants are asked to provide Likert scale ratings of their confidence or belief in experiencing certain events in childhood, and following imagination of those events, ratings are provided a second time to assess changes (specifically increases) in those ratings. One possible problem with this procedure is a lack of control over the veracity of experiences that participants must identify with confidence ratings both prior to and after the imagery phase. In some studies, researchers consult family members for corroboration[20]; however, a majority of the research examining imagination inflation relies solely on the word of the participant.

DRM procedures offer methodological advantages over other memory paradigms, including imagination inflation procedures, because researchers maintain control over the content being activated in working memory through the design of the lists. Specifically, researchers select the list items according to their associative strength to the critical lure and can easily measure when a participant commits the targeted memory error (*e.g.*, chair was not on the studied list but was recalled at test). This content control provides insight into processes that drive associative memory errors, affording researchers the opportunity to explore other potentially important factors driving false memory errors, such as the construction of visual images during list encoding[21] or even elaborating on the list items to generate complex event narratives[11].

This protocol employs a presentation administration of materials and a paper and pencil format of data collection that allows researchers to collect participant data in large groups (*e.g.*, classrooms), while systematically varying variables. The accessibility and experimental control offered by this protocol provides an opportunity to teach students about memory processes with an in-class demonstration while reliably collecting data. Compared to laboratory-based DRM procedures, this context makes results more applicable to classroom learning, thus informing both cognitive science and educational psychology. In addition, this protocol provides optional modifications that can be utilized to remove the usage of imagery instructions or varying list types, thereby offering a construction-kit type approach that allows for more personalized use.

**PROTOCOL:**

All methods described here have been approved by the Institutional Review Board of Georgia State University.

**1. Material Preparation**

1.1. Using the word lists attached in the supplemental materials, create four separate presentations: Imagery A, Imagery B, Non-imagery A, and Non-imagery B. Ensure that all four presentations are void of templates or designs, with white backgrounds and black font. The two list orders, A and B, serve to balance any effects of list order or fatigue. The two imagery versions serve to assess the effects of imagery instructions on memory.

1.1.1. Begin each presentation with a content slide titled, “Instructions”. In the body of the instructions slide, include the relevant instructions listed below in 24+ point font according to whether the presentation is designated as imagery or non-imagery.

1.1.1.1. Include these instructions for Imagery A and Imagery B presentations: “I will present words from a list, one at a time, on the projector. As each word is presented, please create a mental image of that word in your mind. Please do not mark on the packet while the list is being presented. When each list is finished, the projector will indicate, “RECALL”, and you will write down the words you remember from the list in the packet provided. Try to use the images you created to help you recall the words. After you have written down all the words that you can remember, please indicate overall how easy it was for you to create mental images for that list. You will be given 45 seconds to recall the list and rate the ease of creating images, and then we will move on to the next list. When we do so, please flip to the next page in the packet. It is important that you do not revisit any old lists once we have moved on. There will be 11 lists in total, the first being a practice list. After all the lists have been presented, you will be asked to complete a word search task.”

1.1.1.2. Include these instructions for Non-imagery A and Non-imagery B presentations: “I will present words from a list, one at a time, on the projector. Pay attention to the words on the projector. Please do not mark on your packet as the words are being presented. When each list is finished, the projector will indicate “RECALL”, and you will write down the words you remember from the list in the packet provided. You will be given 45 seconds to recall as many words from the list as you can, then we will move on to the next list. When we do so, please flip to the next page in the packet. It is important that you do not revisit any old lists once we have moved on. There will be 11 lists in total, the first being a practice list. After all the lists have been presented, you will be asked to complete a word search task."

1.1.2. Following the instructional slide, create timed slides to present lists and prompt recall. All text is center-aligned. List words are 72 point font, and all instructional cues are 44 pt. font.

1.1.2.1 Create slide 2 and include the text "Prepare for the practice list" centered vertically and horizontally on the slide in 44 point font.

1.1.2.2. On slides 3-10, present the practice list words in order, one word per slide, centered horizontally and vertically, in lower case font. Designate a slide duration of 5 seconds by going under Transitions in the menu and selecting to advance the slide after 00:05.00.

1.1.2.3. On slide 11, indicate the end of the practice list and the beginning of recall. Include "End of Practice List" in black font with "RECALL" double-spaced below it in red font. Designate a slide duration of 45 seconds.

1.1.3. After the practice list recall slide, create slides to present the test lists in the same manner.

Note: The procedure for each list is 10 slides long. The first slide indicates "Prepare for List X". The following 8 slides include the list words in order, each on a separate slide with 5 second durations. Following the list word slides, a recall slide with a designated duration of 45 seconds indicates "End of List X" in black font with "RECALL" double-spaced beneath it in red font. Adapt the "X" in the "End of List X" text to indicate the order of the lists in that particular presentation, not the order of the lists as they are listed in the appendix. For example, the 3rd list to occur in the presentation will read "End of List 3".

1.1.4. Ensure that the order of the lists in the slides varies according to the particular presentation . According to the numbered designations in the word lists attached to the supplemental materials, Imagery A and Non-Imagery A presentations present lists in ascending order: practice, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Imagery B and Non-imagery B presentations present lists in descending order: practice, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1.

1.1.5. After the recall slide for the last list, ensure that slide 112 includes the following text "End of word lists. Turn to the next page in your packets and please take the next 7 minutes to work on the attached word searches." Designate a slide duration of 7 minutes.

1.1.6. Create slide 113 to include "End of word searching. One last activity". This slide has no designated duration. Create a final slide, 114, that includes a thank you.

1.2. Create two different versions of recall packets, imagery and non-imagery, in a word processor. Page 1 of both versions prompts participants to write down their name, gender, age, major, or any other demographic variables of interest. Page 13 of both versions includes a word search with dimensions of 20 x 20 letters or larger. Ensure that no list or practice words occur in the word search.

1.2.1. Ensure that pages 2-12 in the recall packets include repeated recall activity pages, which vary according to the version.

1.2.2. Ensure that recall activity pages for the imagery version include the following instructions at the top of the page: “Instructions: Create an image of each item in your head. Use the images you created to help you recall the words.” Below that, the activity page includes “Recall:” with at least ⅓ of the page following it left blank. At the bottom of the page, include the following prompt: “Overall, how easily did these images come to mind for this list? Circle one”. Below the ease of imagery prompt, include the following options for participants to circle: “0 - Not easy, 1 - Somewhat easy, 2 - Very easy”.

1.2.3. Ensure that recall activity pages for the non-imagery version include the following instructions at the top of the page: “Instructions: Please recall and write down all the words you remember from the current list.” Below that, the page indicates “Recall:” with no other prompts following.

1.3. Obtain the final recognition test from the supplementary materials and do not attach it to the recall packets. It is an individual page to be handed out separately. The final recognition test consists of 80 items total.

1.3.1. Of the 80 items, use 30 from the lists presented on the presentation slides at the start of the study. The 30 presented items chosen for the recognition memory test are the 1st, 3rd and 7th words from each of the 10 lists presented (15 semantic items and 15 phonological items).

1.3.2. Include each of the 10 critical lures related to the 10 presented lists (5 semantic and 5 phonological) on the test.

1.3.3. For the additional 40 items, use the DRM lists *not* presented to participants, including the 1st, 3rd and 7th items from each of 10 non-presented lists (15 semantic and 15 phonological items), as well as the associated critical lure (5 semantic and 5 phonological) for each of the 10 non-presented lists. The non-presented lists are located along with the presented lists in supplementary materials.

1.3.4. Arrange the items on the recognition memory test such that one item from each of the 10 presented lists and 10 non-presented lists appears prior to any critical lures. List items are not thematically blocked on the memory test.

1.3.5. Ensure that instructions on the recognition test prompt participants to indicate “yes” or “no” in writing as to whether each item appeared in any of the lists presented.

**2. Recruitment**

2.1. Recruit at least four face-to-face sections of the same, or very similar, undergraduate class. If possible, recruit non-psychology classes or introductory courses that have not learned about false memory paradigms.

2.1.3. Include all students who are enrolled in the recruited classes and have normal or corrected vision to participate.

2.2. Assign each class section to 1 of the 4 presentation types, distributing the number of classes assigned to each presentation type as evenly as possible and prioritizing even distribution across imagery and non-imagery presentation types.

**3. Optional Modifications to Protocol**

3.1. If the effects of imagery instructions are not of interest, modify the protocol as follows to only include one set of instructions, one type of recall packet, and shorter slide durations.

3.1.1. Using the word lists attached in supplemental materials, create 2 separate presentations, versions A and B. Present the 10 study lists in ascending order following the practice list in the version A presentation (practice, 1, 2, 3, 4…), and present the lists in descending order following the practice list in the version B presentation (practice, 10, 9, 8, 7…).

3.1.2. Include the non-imagery instructions from protocol item 1.1.1.2 on the first slide of both presentation versions.

3.1.3. Modify the timed list presentation slides described in 1.1.2.2 to be 2 seconds long instead of 5 seconds. In other words, design the presentation so that each word is presented to participants for 2 seconds. Do not modify any other types of timed slides, like the recall slides (45 seconds) or word search side (7 minutes).

3.1.4. Create 1 version of the recall packet (*i.e.,* non-imagery version) that includes the traditional non-imagery instructions from protocol item 1.2.3.

3.1.5. Assign the recruited classes to the 2 presentation types as evenly as possible.

3.2. If the effects of list type (semantic *vs.* phonological) are not of interest, modify the protocol as follows to only include longer, traditional semantic DRM lists:

3.2.1. Do not use the word lists included in our supplementary materials, with the exception of the practice list. Instead, select 20 of the unmodified DRM lists included in the original Roediger & McDermott study[2]. These word lists are 15-items long and all semantically related. Number the selected lists 1-20. Use lists 1-10 as study lists in the presentation and lists 11-20 as filler lists for the recognition test.

3.2.2. Modify the presentations to accommodate 15-item lists instead of 8-item lists. Following the instruction slide and practice list, the procedure for each test list is 17 slides long. For each list, the first slide indicates “Prepare for List X”, the following 15 slides present the list words one at a time, and the last slide for the list indicates the end of the list and the beginning of recall.

3.2.3. Modify the recognition test design described in 1.3 to include the 1st, 8th, and 10th words from the 10 study lists and 10 filler lists and their critical lures.

**4. Procedure**

4.1. At the beginning of a regularly scheduled class session, ask the instructor to leave the room and pull up the presentation that was assigned to that class section.

4.2. Introduce yourself as the researcher and distribute informed consent forms to students. Allow students to read through the informed consent document on their own. Prompt them to complete the informed consent form and to ask any questions about the document or participation.

4.3. Distribute the appropriate recall packets to participants. If using an imagery condition, ensure that classes who were assigned one of the two imagery presentations receive an imagery recall packet. Do not distribute the recognition test yet.

4.4. Instruct participants to fill out the initial page of the recall packet with demographic information. Then read the instructions from the presentation aloud with the slide presented.

4.5. Instruct participants to flip to the next page in their packet for the practice list, move to presentation slide 3 (*i.e.,* “Prepare for the practice list”), and read the prompt aloud. After reading the prompt, move to slide 4 and allow the presentation to progress through the timed practice list slides.

4.6. When the practice list recall slide expires and automatically moves to the next list prompt slide (*i.e.,* “Prepare for list 1”), prompt participants to ask any questions they have about the procedure. Answer any questions and instruct participants to turn to the next page (pg. 3) in their packet for list 1.

4.7. Once all participants have turned to the next page in their booklet, read the list 1 prompt slide aloud (*i.e.,* “Prepare for list 1”) and progress to the timed list 1 word list and recall slides.

4.8. Continue this procedure for the 9 remaining lists, prompting participants to flip to the next page in their booklet after each recall slide expires, reading the “prepare for list X” slide aloud, and subsequently prompting the timed list slides.

4.9. After recall for list 10, supervise as the presentation prompts participants to turn to the next page in their packet and work on the word search for 7 minutes.

4.10. When the presentation automatically progresses to the final slide (*i.e.,* "One last activity"), collect the recall packets from participants and distribute the final recognition test.

4.11. Instruct participants to complete the final recognition test at their own pace and to do their best not to leave any items blank. Once all participants have finished the test, collect the recognition tests and verbally debrief participants (see supplementary materials for debriefing statement).

## REPRESENTATIVE RESULTS:

### Effects of DRM Procedures on False Memories: Standard DRM Instructions without Imagery

To illustrate standard DRM procedures' ability to induce false memories, we analyzed rates of falsely remembering non-list words during recall and recognition. **Table 1** reports proportions for the different types of false remembering that occurred during recall and recognition. During immediate recall, participants recalled unpresented words on 20% of the lists, suggesting the protocol induced spreading activation to unpresented words that were then immediately remembered as being seen on 1 out of every 5 lists. Of those false recalls, 13% were recalls of the critical lures and 8% were recalls of other non-list words, which we refer to as non-critical lures. A repeated measures analyses comparing the proportion of lists in which the critical lure was recalled and the proportion of lists in which a non-critical lure was recalled indicated that participants recalled critical lures at significantly higher rates than non-critical lures, $F(1, 48) = 9.24$, $p = .004$. While this finding suggests that the DRM protocol successfully converged on and activated the critical lures more so than other words, it was not to the degree that longer DRM lists typically do. For instance, the longer 15-item lists described in protocol modification 3.2 can induce recall of the critical lure up to 55% of the time[2].

To measure the effects of DRM procedures on the *recognition* of critical lures during the final recognition test, we compared the proportion of critical lures remembered (number of "yes" recognitions/10) to the proportion of non-critical lures remembered, which included filler list words used as distractors and their critical lures (number of "yes" recognitions/40). Repeated measures comparisons of these proportions indicated that critical lures were recognized at significantly higher rates than non-critical lures, $F(1, 48) = 149.52$, $p < .001$. Critical lures were recognized 45% of the time, whereas distractor words were only recognized 6% of the time, illustrating that the protocol induced high rates of false critical lure recognition.

When directly comparing rates of false memories across recall and recognition, a repeated measures analysis indicated that significantly higher proportions of critical lures were remembered during the recognition test (45%) than during immediate recall (13%), $F(1, 48) = 145.14$, $p < .001$. This finding is typical and demonstrates the different demands that each task places on memory and also illustrates the ability of this protocol, which utilized both types of memory tasks, to capture instances of false memory that were present during one task but not the other. The final recognition task measured instances of false memory that were absent during free recall.

To compare the effects of using phonologically-related *versus* semantically-related DRM lists on false memories, we calculated separate proportions of critical lure recall and critical lure recognition for each list type (number recalled or recognized/5). See **Table 1** for proportions of false memories across list types. A 2 (test type: recall *vs.* recognition) x 2 (list type: semantic *vs.* phonological) mixed ANOVA indicated that critical lures for phonological lists were *recalled* at higher rates than critical lures for semantic lists (rates of 14% and 6%, respectively); whereas critical lures for semantic lists were later *recognized* at higher rates than critical lures for phonological lists (rates of 48% and 28%, respectively). This was evidenced by a significant interaction between list type and test type for false memories, $F(1, 100) = 55.36$, $p < .001$. This finding demonstrates that the type of association between the list words affects the type and/or level of processing induced during study (*i.e.,* differences in recall performance) and later remembering (*i.e.,* differences in recognition performance). Semantic lists induce deeper processing of the list association and critical lure, which makes reactivation of that critical lure particularly difficult to monitor during recognition; whereas phonological lists induce shallow associative processing that is confusing and hard to monitor during recall but that largely decays by the final recognition test.

**Effects of Imagery Instructions during DRM Procedures**

To demonstrate the effects of modified DRM procedures that instruct participants to create mental images of the list words, we compared hit rates (*e.g.*, correctly recalling a list word) and false memory rates across participants in imagery and non-imagery conditions. We calculated separate proportions for recall and recognition hit rates by dividing the total number of list words correctly recalled by 10 and the total number of "yes" responses to list words on the recognition test by 30. A 2 (imagery *vs.* non-imagery) x 2 (proportion of recall hits *vs.* proportion of recognition hits) mixed ANOVA indicated a significant main effect for imagery instructions. Participants in the imagery condition remembered more list words than participants in the non-imagery condition during both recall (64% *vs.* 60%) and recognition (93% *vs.* 88%), $F(1, 100) = 5.90$, $p = .02$. A similar 2 (imagery *vs.* non-imagery) x 2 (proportion of critical lures recalled *vs.* proportion of critical lures recognized) mixed ANOVA on false memory rates indicated another main effect for imagery instructions, $F(1, 100) = 3.82$, $p = .05$. Participants who imagined the list words remembered fewer critical lures than participants receiving standard DRM procedures during both recall (7% *vs.* 13%) and recognition (39% *vs.* 45%).

A larger mixed model with list type added in as an additional repeated measure factor did not indicate any significant interaction between list type and imagery; imagery affected memory for both list types similarly. However, it is important to note that when list type was added to the mixed model, the impact of imagery on false recognition was only marginally significant, $F(1,100) = 3.46$, $p = .066$. Previous work has also indicated null effects of imagery during false memory recognition[10], suggesting that simple imagery instructions (*i.e.,* create a mental image in your head) are not sufficient aid during monitoring when the critical lure is reactivated during recognition. The relative decreases in false recall and increases in list word recall and recognition reported here are in line with previous work employing imagery instructions in DRM procedures[10,23]. Further, the effects of imagery would likely be more pronounced if protocol modification 3.2 was implemented, which utilizes longer semantically-related lists[10].

## FIGURE AND TABLE LEGENDS:

**Table 1: Proportions of the Different Types of Words Falsely Remembered Following Standard Instructions.** This table illustrates the proportions of the various types of words falsely remembered by the non-imagery group. Rates of false memories for critical lures and non-critical lures are illustrated across test type and list type.

**Figure 1: Comparisons of Imagery and Non-Imagery.** This figure illustrates the proportions of list words accurately remembered and the proportions of critical lures falsely remembered during recall and recognition across imagery and non-imagery conditions. Error bars represent the standard errors.

## DISCUSSION:

The protocol employed in this study modified a widely used word list procedure, the Deese Roediger McDermott (DRM) paradigm, to assess the effects of associative processing with and without imagery instructions on false memories in a classroom-based procedure. The expansion to include the variables of list association type, test type, and imagery instruction implemented here afforded the ability to analyze how each of these complex factors influenced a learning context independently, as well as how they interacted, providing insight into memory processing strategies. This protocol also offers optional modifications that can be used if a more traditional DRM procedure is desired, wherein imagery instructions or different list types are employed. These modifications can be implemented by only using the non-imagery condition with shortened presentation durations and/or substituting longer semantically-related word lists.

The automated presentation of DRM materials described in this protocol affords absolute control of presentation duration, which is an essential element to control considering that the length of presentation duration impacts recall across phonological and semantic lists differently[22]. A relatively long 5-second presentation duration was employed here to allow time for participants to engage in imagery procedures. However, the presentation can be easily modified (see protocol 3.1) to utilize shorter presentation durations when imagery is not being used. Shorter durations are associated with increased false memory rates for both phonological and semantic lists[22]. This automated format also allows for systematic control of list order presentation, which is necessary for counterbalancing the presentation of both list types. The false memory rates for phonological and semantic lists reported here suggests that the protocol’s alternating presentation of list types successfully induced the associative processing inherent to each list type, and the significant interaction between list type and test type reported here demonstrates that phonological and semantic associative processing apply different constraints on memory.

The simple imagery instructions employed here were sufficient to significantly increase memory for list words and decrease false memory recall, but were not sufficient to decrease false recognition after a distractor activity. Using imagery instructions in this context not only provides insight into the mechanisms responsible for associative processing and source monitoring during classroom learning, but also has the ability to demonstrate the usefulness of creating visual memory cues to students.

The word lists included in this protocol were modified from previously normed word lists[9] to only include concrete words that participants could mentally represent with visual imagery. Less concrete words (*e.g.*, worst, dug, pun, accident, *etc.*) were removed from 16-item lists, resulting in shorter 8-item lists. While our shorter lists frequently created false memories in participants during recall, they did not converge onto one specific critical lure to the extent that longer lists typically do; they activated other related words that were misremembered in addition to the critical lures. This illustrates the function of list length on the convergence of associative processing onto one critical lure. Thus, false memories may be underestimated during recall when using shorter lists if other related non-list words are not taken into account. If phonological processing is not of interest, the 3.2 protocol modification can be utilized to increase false memory rates using longer semantically-related lists.

This protocol utilizes immediate recall and final recognition tests. When both of these assessments are used in conjunction and separated by a delay (*i.e.,* the 7-minute word search), instances of false memory that may not be captured by one task can be captured by the other. For instance, our immediate recall task captured phonological false memories that had decayed by final recognition, and our final recognition task captured semantic false memories that were successfully monitored, or possibly not activated, during immediate recall. The combined use of both tasks provides a more comprehensive examination of the mechanisms responsible for false memories, namely activation and monitoring. Depending on the variables of interest, this protocol can be easily adapted beyond the specific modifications provided here by varying presentation versions by a single variable and comparing recall and recognition performance across versions. It is our hope that this adaptability and construction-kit approach offered here proves particularly useful for research and classroom usage.

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**DISCLOSURES:**

The authors have nothing to disclose.

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Figure 

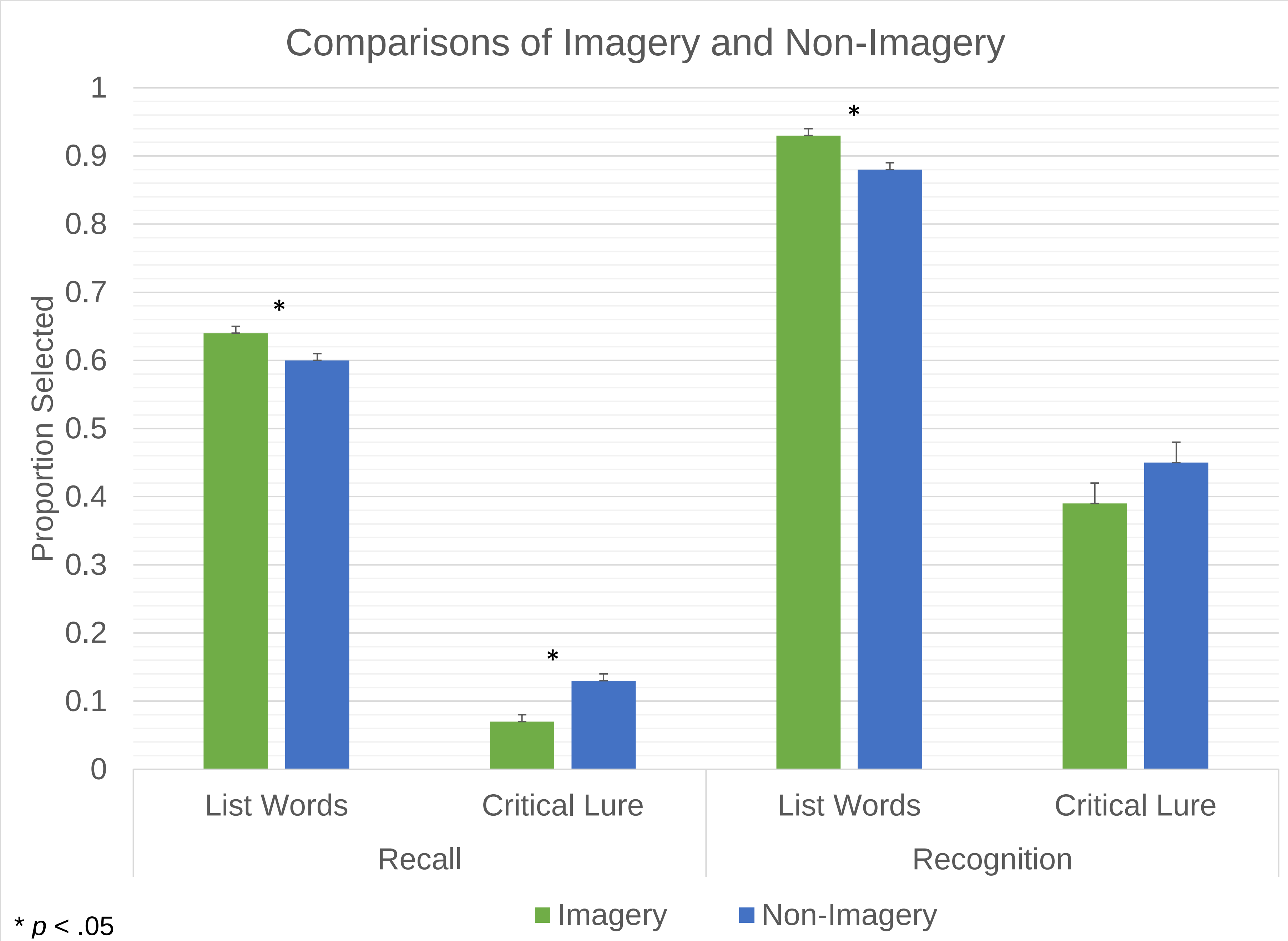
Comparisons of Imagery and Non-Imagery
Proportion Selected
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
*
*
*
List Words
Critical Lure
List Words
Critical Lure
Recall
Recognition
Imagery
Non-Imagery
* p < .05

 

**Table 1**. Proportions of the Different Types
Falsely Remembered Following Standard In

| Item Type | | Recalled |
|---|---|---|
| Critical Lures | | |
| | Semantic | .08 |
| | Phonological | .18 |
| | Overall | .13 |
| Non-Critical Lures | | |
| | Semantic | .03 |
| | Phonological | .12 |
| | Overall | .08 |

| of Words<br>ıstructions |
| --- |
| Recognized |
| .51 |
| .38 |
| .45 |
| |
| .04 |
| .07 |
| .06 |

| Name of Material/ Equipment | Company | Catalog Number | Comments/Description |
|---|---|---|---|
| No Materials Applicable | | | |

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Author(s): Merrin Oliver, Rebecca Bays, and Cameron Miller

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August 9, 2018

Dear JoVE Peer Review,

We are grateful to the editor, reviewers, and peer review staff for their time and constructive comments regarding the initial submission of our manuscript *Using a Classroom-Based Deese Roediger McDermott Paradigm to Assess the Effects of Imagery on False Memories.* We thoroughly considering each comment and implemented all recommendations possible. While using actual track changes was not feasible through our collaboration in Google docs, we took special care to highlight all changes made in response to the peer review in red, as we did not want to confuse highlighted edits with highlighted protocol text for production. Below, we provide the initial editorial and reviewer comments followed by our response to each one, including detail of any revisions. We hope that you find our revisions sufficient and informative.

Best regards,

Merrin Oliver, Brooke Bays, and Cameron Miller

**Editorial comments:**

**1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.**

*Our response*: Thank you, we have done our best to ensure there are no remaining spelling or grammar issues.

**2. Please revise lines 60-65 and 69-73 to avoid previously published text.**

*Our response*: We paraphrased  the lines cited to avoid any previously published text.

**3. Please upload Table 1 to your Editorial Manager account. It is missing from the current submission.**

*Our response: We uploaded the table as an .xls file, per the instructions.*

**4. Please ensure that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., "Do this," "Ensure that," etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as "could be," "should be," and "would be" throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a "Note." However, notes should be concise and used sparingly. Please include all safety procedures and use of hoods, etc.**

*Our response*: We revised all protocol text to be in the imperative tense. Most often, this included replacing "should" phrases with "ensure" or "are" phrases.

**5. Please revise to explain the Representative Results in the context of the technique you**

**have described, e.g., how do these results show the technique, suggestions about how to analyze the outcome, etc.**

*Our response*: While we attempted to do this in the first submission, we revised the entire results section to be more descriptive in terms of relating the materials and procedure to our outcome, typical outcomes, and their interpretation. In an effort to provide results that were more representative of traditional DRM procedures, we revised the results section to focus on recall and recognition using typical (non-imagery) instruction before detailing the effects of our imagery modification. In addition to focusing more on standard DRM analyses and outcomes, we added more detail to the description of the analyses being used and the variables themselves. For instance, instead of saying "Repeated measures analysis indicated that participants recognized critical lures at significantly higher rates than other non-list words" we revised to say "To measure the effects of DRM procedures on the recognition of critical lures during the final recognition test, we compared the proportion of critical lures remembered (number of "yes" recognitions/10) to the proportion of all other non-studied words remembered (number of "yes" recognitions/40). Repeated measures comparisons of these proportions indicated that critical lures were recognized at significantly higher rates than distractor words, $F(1, 48) = 149.52$, $p < .001$." We made these types of changes throughout.

**Reviewers' comments:**

**Reviewer #1:**

**General impression:**
**This is - as far as I can see - a clear and detailed description (with minor exceptions that could be easily addressed, see below) of the DRM (Deese-Roediger-McDermott) procedure with an added imagery manipulation and also using both phonologically and semantically similar word lists. As such, I can't see any reason why it shouldn't be suitable as a Visualized Experiment in JoVE.**

**Having said that, and keeping in mind that JoVE aims for contributions that allow the audience to learn a certain scientific technique, I should add that the particular study/procedure the authors present in their manuscript is a rather special implementation of the general DRM technique (i.e. with the added imagery manipulation that is not a core part of the DRM procedure). It might be worth considering, therefore, a revision of the manuscript that also includes a more basic DRM procedure (or that separates the essential DRM parts from the optional added manipulation in the presentation), i.e. a sort of construction kit approach, which would enhance the usefulness of the contribution for the JoVE audience in my view.**

*Our response: We agreed that our modified version of the DRM paradigm is somewhat specific (as a result of our research questions) and may not be as useful as standard DRM procedures to a wider audience. Thus, we revised the protocol to include a more construction-kit type approach as suggested. We could not revise the primary protocol to demonstrate standard DRM procedures and then detail* *how to add in imagery or list type, because our results are not necessarily representative of that. However, we did add in protocol section* ***3. Optional Modifications to Protocol,*** *which details how to modify the protocol if imagery instructions and/or list type are not of interest. We subsequently discuss the possible modifications throughout the results and discussion as well.*

**Specific points:**

*** Protocol, 1.1.4.: I didn't understand the idea behind the two versions A and B - what is the benefit of rotating the sequence of the lists by just one list? I can't see any at the moment. Please either explain what the reason behind your particular order manipulation is or come up with a more convincing one (or perhaps none at all? I'm not sure if the procedure would lose anything, and it would be easier to administer with just two versions instead of four ...). (...) Much later I found the answer in line 375 of the manuscript - phonological and semantic lists are alternated in the presentation, and the order manipulation makes sure that half of the participants start with a phonological list and the other with a semantic one. That makes sense, but it would have been easier if the authors had said that right away ...**

*Our response: We added in an explanation immediately after describing the two versions in 1.1.*

**** Line 325, "This finding suggests the distractor activity employed in this study was effective" - I can't follow this logic; recognition is almost always higher than recall, this doesn't need to have anything to do with a distractor activity between the two measures; i.e. I'd reconsider this sentence.***

*Our response: We deleted this sentence.*

*** Figure 1: I personally find the two bars on top of each other quite confusing, certainly they make it difficult to see the associated interaction the authors report in the results section (apart from this, they are non-standard in psychological journals, and psychologists would be the main audience for this paper).**

*Our response: We revised figure 1 to depict imagery comparisons using a standard bar chart with error bars.*

*** Table 1?? - I couldn't find Table 1 anywhere in the manuscript.**

*Our response: We made sure to include Table 1 in the submission. Although per instructions, it is not included in the manuscript itself.*

**Reviewer #2:**

**This presentation with slide is already used for collecting data when the DRM lists are visually presented, I do not understand what it is new in this procedure? (See, Gallo, D. A. (2006). Associative illusions of memory)**

*Our response: We are not claiming that our manner of presentation is new, and we cite (page 3, line 12) that we adapted this powerpoint encoding procedure specifically from a previous Ballou and Sommers study varying list types. However, we do make a claim that this protocol is the first to look at* *the impact of imagery instructions on such presentation of alternating semantic and phonological lists.*

**Imagery ratings should be made after each word because concrete words are not equal in their ability to evoke a visual image (see norms of imagery values for concrete words).**
*Our response: It is our understanding that we are writing this protocol to describe the procedures in previously published work. While we might agree in hindsight that adding an imagery rating after each individual word might increase the sensitivity of that measure, we are reporting on something that has already been done. In the original study, we were concerned that we would not be able to control for the processing that occurred as a result of making so many evaluations of imagery ease. This would cause participants in the imagery condition to engage in 100 additional instances of evaluative processing that the non-imagery group would not be engaging in. Thus, it would be hard to disentangle the effects of imagery from the effects of making imagery ratings.*

**It would be interesting to estimate the participants' imagery abilities before the study because this variable could affect the ease which they use imagery during the study phase.**
*Our response: Yes, this would be very interesting!*

**Imagery value of words are not been estimate. This factor affects the creation of visual images.**
*Our response: We were not able to report on something here that was done in the originally published work.*

**The procedure causes problem because visual presentation of words interferes with the imagery instruction. Indeed, it is well known (Kosslyn & Swartz, 1977; Kosslyn, Brunn, Cave, & Wallach, 1984; Kosslyn et al., 2006) that imagery is an activity closely related to visual perception. There are functional and structural similarities between perception and imagery suggesting that the two faculties share resources and cognitive processes.**
*Our response: Again, we cannot change the method for the previously published work. However, we would be very interested to see a study that varied presentation modality across imagery instruction.*

**(1.1.2.2.) the slide duration of 5 seconds is too long. DRM studies have shown that false memories decrease according to the presentation time. A presentation time over than 3 seconds decreases false memories significantly, like it was also the case with DRM lists fewer than 10 words or with a visual presentation compared to an oral presentation.**
*Our response: We have added notes throughout the results and discussion that shortening the encoding duration or increasing the length of lists would likely increase false memory rates. Additionally, we added option modifications to the protocol to use longer lists or shortened presentation durations.*

**(1.1.4.) It would be better to use two order of lists presentation: the following order 1-2-3-4-5-6-7-8-9-10 for the half of participants in the imagery and non-imagery conditions A & B**

**and the order 10-9-8-7-6-5-4-3-2-1 for the other half of participants in the imagery and non-imagery conditions A & B**
*Our response: We made this change to the protocol.*

**Theoretical limits:**
**According to the Paivio's dual coding theory, words are verbally represented (i.e. a graphemic or phonological representations) and concrete words can be represented by a visual image (i.e. a visual image of the object designated by the word). These both representations (verbal vs. imagined) are different. Verbal representations are arbitrary whereas visual images are analogical (see for a review Finke, 1983; Paivio, 1991). The authors of the present paper confuse these representations when they wrote "visual images of word". In fact, visual images of words correspond to graphemic or phonological representation that both result from a verbal coding. In addition, elaborate an image from a word implies first a semantic processing (automatically) and then an imagining coding (which depends on imagery value of words, individual imagery abilities and the task)**
Our response: While the semantics here are rather nuanced, we changed the phrase cited here to more accurately reflect the instructions that participants received (i.e., create mental images of the word in your mind).

**One reference to be corrected and a more recent on this thematic:**
**Robin, F. (2011). Imagination and False Memories. Imagination, Cognition and Personality, 30(4), 407-424. https://doi.org/10.2190/IC.30.4.e**
**Robin, F., & Mahé, A. (2015). Effects of image and verbal generation on false memory. Imagination, Cognition and Personality, 35(1), 26-46.**
**https://doi.org/10.1177/0276236615574488**
*Our response: We corrected the reference and added the newer reference into the representative results reporting the impacts of imagery.*

## Practice List: Unrelated, no critical lure

Hair
Pencil
Stop
Sky
Car
Taste
Book
Farm

## Test Lists

Do not include the critical lures in list presentation
* Indicates words are included on final recognition test

**List 1)** Critical lure: **Cup** (Semantic)
Mug*
Saucer
Tea*
Coaster
Lid
Coffee
Straw*
Soup

**List 2)** Critical lure**: Dog** (Phonological)
Log*
Hog
Dock*
Bog
Fog
Doll
Frog
Jog*
Dot

**List 3)** Critical lure: **Chair** (Semantic)
Table*
Couch
Desk*
Lamp
Pillow
Stool
Bench*

Rocker

**List 4)** Critical lure: **Gun** (Phonological)
Bun*
One
Gum*
Gut
Nun
Run
Sun*
Gown

**List 5)** Critical lure: **Window** (Semantic)
Door*
Glass
Shade*
Curtain
Shutter
House
Screen*
Sill

**List 6)** Critical lure: **Mail** (Phonological)
Nail*
Meal
Mate*
Hail
Mall
Maid
Sail*
Veil

**List 7)** Critical lure: **Shirt** (Semantic)
Blouse*
Pants
Tie*
Button
Shorts
Collar
Vest*
Sweater

**List 8)** Critical lure: **Man** (Phonological)
Can*
Tan
Map*

Van
Mat
Mad
Pan*
Moon

**List 9)** Critical lure: **Bread** (Semantic)
Butter*
Sandwich
Jelly*
Milk
Flour
Crust
Loaf*
Toast

**List 10)** Critical lure: **Trash** (Phonological)
Gash*
Track
Flash*
Trap
Ash
Crash
Tramp*
Rash

**Non-presented lists**

Below are associated lists that are used as fillers/distractors on the recognition test.
* Indicates words on the recognition test

**Filler List 1)** Critical lure: **Bad** (Phonological)
*Bag**
*Bat*
*Dad**
*Band*
*Pad*
*Sad*
*Bid**
*Lad*

**Filler List 2)** Critical lure: **Ball** (Phonological)
*Wall**
*Fall*
*Bald**
*Tall*
*Bull*

*Bell*
*Hall**
*Boil*

**Filler List 3)** Critical lure: **Beer** (Phonological)
*Rear**
*Gear*
*Beard**
*Deer*
*Bear*
*Fear*
*Ear**
*Sear*

**Filler List 4)** Critical lure: **Hand** (Phonological)
*Land**
*Sand*
*Canned**
*Hound*
*Band*
*Had*
*Hanged**
*Brand*

**Filler List 5)** Critical lure: **Rain** (Phonological)
*Train**
*Ran*
*Lane**
*Raid*
*Rave*
*Vain*
*Brain**
*Range*

**Filler List 6)** Critical lure: **Foot** (Semantic)
*Shoe**
*Toe*
*Sandals**
*Soccerball*
*Ankle*
*Arm*
*Boot**
*Sock*

**Filler List 7)** Critical lure: **Lion** (Semantic)
*Tiger**

*Mane*
*Tamer**
*Whistle*
*Elephant*
*Tigercub*
*Cage**
*Circus*

**Filler List 8)** Critical lure: **Smoke** (Semantic)
*Cigarette**
*Match*
*Ashes**
*Cigar*
*Chimney*
*Tobacco*
*Pipe**
*Ashtray*

**Filler List 9)** Critical lure: **Doctor** (Semantic)
*Nurse**
*Bandaid*
*Stethoscope**
*Needle*
*Aspirin*
*Kleenex*
*Thermometer**
*Syrup*

**Filler List 10)** Critical lure: **Hammer** (Semantic)
*Carpenter**
*Wood*
*Saw**
*Wrench*
*Nail*
*Ruler*
*Scissors**
*Screwdriver*