# Recall-Induced Forgetting of Pictures

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Summer 2022

**Abstract**

Recognition-induced forgetting refers to a visual memory phenomenon in which the initial recognition of certain objects within a category causes the subsequent forgetting of other objects within the same category. Memory for pictures has been studied exclusively using recognition as a method to induce forgetting, assuming that recall of pictures would be too subjective, if not impossible, to measure. Here, for the first time, we ask whether recalling pictures is a viable method for inducing forgetting of visual memory. To this end, we implemented drawing as a recall task in the typical three-phase induced forgetting paradigm. After studying pictures, subjects drew a subset of them from memory. Then memory for all pictures was tested using a recognition memory task. Not only did we find the first evidence of *recall*-induced forgetting of pictures, but we also established the use of drawing individual pictures as a method for studying recall.

## Recall-Induced Forgetting of Pictures

We commonly assume that rehearsing information strictly improves our memory. However, when we practice information, such as which food we need to stock up on in the fridge, we actually reduce our memory for related information that went unpracticed, such as the cereal and bread we needed in the cabinet. Termed *induced-forgetting*, this phenomenon occurs when practicing certain information inhibits the memory of other, semantically-related information (Anderson, Bjork, Bjork, 1994; Maxcey & Woodman, 2014). This phenomenon has primarily been studied with words, with cued recall as the method of practice to induce forgetting—referred to as *retrieval*-induced forgetting (Anderson, Bjork, Bjorn, 1994). More recently, it has also been studied with pictures and recognition, known as *recognition*-induced forgetting (Maxcey & Woodman, 2014). However, it's unclear whether the method of practice impacts this effect for real-world pictures—do we forget pictures only after recognizing related ones, or does any method of retrieval, such as recall, lead to their forgetting? Here, we evaluate whether induced-forgetting of real-world pictures occurs after drawing recall (i.e. recall-induced forgetting[1]).

### Recall versus Recognition

On the one hand, recall and recognition are thought to be two mechanisms to access the same underlying memory representation (Gillund & Shiffrin, 1984; Humphreys, Bain, & Pike, 1989; Murdock, 1982). Therefore, if it's a matter of accessing the representation, then induced-forgetting should happen regardless. Indeed, previous studies have found that induced-forgetting occurs for a wide variety of stimuli using both retrieval and recognition practice methods. Anderson, Bjork, and Bjork (1994) first identified the phenomenon testing

1 Although the retrieval-induced forgetting paradigm also typically uses recall to induce forgetting, the term itself does not disambiguate recognition versus recall. Here we use the term recall-induced forgetting to clearly convey the method of practice and novelty of the present study.

verbal memory, using cued recall of words. Participants studied sets of category-item pairs (e.g., fruit-banana), then later practiced and were tested on them with a free recall task. Their experiment also established the three phase paradigm used to study induced forgetting, with a learning/study phase, practice phase, and test phase. Maxcey, Janakiefski, Megla, Smerdell, and Stallkamp (2019) also found induced forgetting of words using recognition as the method of practice. Participants studied sets of category-item pairs, then practiced them in an old/new recognition task. Pairs were shown one at a time, and participants determined whether the pair was old (i.e. from the study phase) or new. Kovacs and Harris (2022) found the phenomenon to even occur for novel visual stimuli. Participants learned each shape by drawing it immediately after it appeared on a screen. In the practice phase, participants either drew images directly from the screen (restudy practice), or were cued with the color and pattern of the stimulus and asked to draw it from memory (retrieval practice). At test, both groups were cued with the color and pattern for all of the stimuli from the learning phase and tasked with drawing the corresponding shape. The induced forgetting effect was only observed for items in the retrieval practice category; accuracy was highest for the cued recall shapes and lowest for the non-practiced shapes of the same color. Though this study revealed retrieval-induced forgetting to affect visual memory, it is unclear whether the impairment would affect memories of real-world pictures of objects, as these images are far more complex in nature.

Additionally, research has shown that induced-forgetting of pictures occurs if only restudying practiced images in the practice phase—even in the absence of recognition or recall (Maxcey, Janakiefski, et al., 2019; Megla, Woodman, & Maxcey, 2021, but see Kovacs and Harris, 2022). We also know that induced forgetting is incredibly robust and occurs for many types of stimuli. Studies have found that induced forgetting affects even emotionally salient stimuli that were thought to have enhanced memory (Brady & Bainbridge, 2022, How to Induce the Forgetting of Pictures). Rugo et al. (2017) utilized the typical induced forgetting paradigm, using human faces as their stimuli. Recognition-induced forgetting did occur in their study, revealing that even faces are not immune to this kind of forgetting. Knowledge of the effect still does not prevent its occurrence—participants experienced the memory impairment even after viewing a video explaining the phenomenon (Maxcey, Deszo, et al., 2019). Given the robustness of the induced-forgetting memory impairment, we may still expect it to occur after practice with recall.

On the other hand, though there has been evidence for retrieval-induced forgetting of verbal stimuli and evidence of recognition-induced forgetting of pictures, we cannot automatically assume the existence of recall-induced forgetting of pictures. For one, positron emission tomography (PET) scans—which use tracers to capture brain activity- have revealed retrieval to be a more difficult task than recognition. Cabeza et al. (1997) had university students study sets of word pairs (e.g. parents-piano) lying in the PET scan machine. Participants in the recognition condition were shown word pairs and had to decide whether the pair was one that they had studied. The recall condition provided participants with the first word and tasked them with verbally reporting its pair. The scans demonstrated that four brain areas—the left cerebellum, right thalamus area, right globus palladius, and the anterior cingulate area- were more active during recall, and thus that recall requires more brain activity and is a more difficult task than recognition. There is also literature suggesting that whereas only true recollection is involved in recall, having a sense of familiarity with a stimulus can help in recognition tasks. When testing samples of people with amnesia, forced-choice recognition abilities remained relatively intact, while free recall was significantly impaired (Hirst et al., 1988; Bastin et al., 2004).

In addition to levels of brain activity, recognition and recall are different mechanisms and are not always affected the same way. For example, the memorability of an object—which describes the statistical distinctiveness of a certain stimulus (Isola et al., 2011; Bylinskii et al., 2015)- has a significant effect on our ability to recognize that object; the more memorable an object is the more likely we are to recognize it in the future (Bainbridge, Hall, & Baker, 2019). Memorability does not, though, impact our ability to freely recall objects. People have been shown to recall similar amounts of low memorable and high memorable objects (Bainbridge, Hall, & Baker, 2019). Adding to their differences, people with aphantasia—who lack mental imagery—only have difficulty when recalling images from memory, but have an intact ability to recognize those same images (Bainbridge, Pounder, Eardley, & Baker, 2019). Only their visual recall is impaired, suggesting a dissociation between recall and recognition. One study using Additionally, pictures are far more complex and individually unique than words. For example, the single word “dog” can be used to describe infinite pictures of dogs of different breeds, colorings, sizes, and ages. Many pictures could even be drawn of the same dog in different positions or from different angles. For these reasons, we cannot be sure that recall-induced forgetting of real-world objects would occur without studying it independently.

**Drawing as a Tool to Study Memory**

Until recently, it was believed that the recall of real-world pictures could not be easily studied; the use of drawings as an output was not thought to be quantifiable. Indeed, previous research studying the recall of visual stimuli has largely only focused on the recall ability of only one feature of the stimulus, such as the color (Scotti et al., 2020) of objects. However, Bainbridge (2021) recently presented a tutorial on implementing drawing-based studies, specifically how to quantify drawings into useful data. Drawing provides rich insight into our memories beyond a few features. Through drawing, we can quantify color, object detail, which objects are being remembered, and which are forgotten. Drawing studies can measure the accuracy of our spatial memory and our false memories for objects not present. Tracking mouse movement even allows researchers to measure when objects are being remembered. Bainbridge's tutorial explains that the crucial element of an effective drawing study is clear scoring criteria to accurately and uniformly quantify the drawn data. Her tutorial lists two scoring methods that are relevant to this study: drawing judgment, which has scorers compare drawings as a whole to the original stimulus and decide if they are the same, and object selection, which tasks scorers with matching objects within images.

In fact, this drawing method has recently been shown to provide rich insight into visual memory. Bainbridge, Hall, and Baker (2019) ran a series of experiments that further established drawing as a tool to identify the content and quality of visual memory. The main experiment was a delayed free recall task, in which participants were shown 30 images, then later asked to draw these images from memory. Their drawings were compared to the drawings of participants from three other conditions: The immediate recall condition had participants draw each image immediately after viewing it, the image drawing condition allowed participants to look at the images while they drew, and the category drawing condition had participants draw images based on a category name (e.g., amusement park) rather than from looking at an image. Analyses of each condition found that the drawings from the delayed condition were more accurately detailed than those from the category drawing task but less detailed than both the image drawing and the immediate recall tasks. From this, researchers concluded that participants' memories contained more information than the canonical category representation, but that some of this information was lost over the delay between stimulus presentation and testing. Using these same methods, Bainbridge, Pounder, et al. (2019) were able to provide rich insight into aphantasic memory, finding significantly impaired memory of objects, with less color and fewer details, but intact spatial memory and fewer falsely recalled objects. These papers introduced the possibility of using drawing as a method of representing visual memories, and that these representations can be quantified into useful data.

**Current Study**

In the current study, we use this newly developed drawing method to capture memory representations and become the first to evaluate recall-induced forgetting of pictures. Our study borrows the study and practice phases directly from classic recognition-induced forgetting studies of real-world pictures (Maxcey and Woodman, 2014), only altering the method of practice. Participants began with the study phase, in which they were shown a series of images of real-world objects one at a time. In place of the typical practice phase of induced forgetting studies, in which participants identify which images they had seen in the previous phase, our study tasked participants with freely recalling images from the first phase, asking them to draw any two images from four different categories. Lastly, participants were tested on their memory with an old/new recognition task in the final test phase, where half of the images were those shown in the first phase, and the other half were new images belonging to the same semantic categories. If participants experience recall-induced forgetting of pictures then they will have improved memory for the items they drew in the practice phase at the cost of worse memory for the other items from practiced categories that they did not draw. This would suggest that the effect occurs by simply accessing the practiced memory representations, regardless of the retrieval mechanism. But, if the memory impairment is instead dependent on the method of practice, then we should not find the forgetting of related objects. To preview the results, our participants performed significantly better on practiced images at test compared to baseline. Additionally, participants' scores on the related items at test were significantly worse than those for baseline items. In other words, we found retrieval-induced forgetting of real-world images, suggesting the induced-forgetting occurs regardless of the retrieval mechanism.

## Methods

### Participants

Sixty participants were recruited through SONA, Vanderbilt University's psychology participant recruitment system (36 women, 14 men; mean age = 19.6). The participants received course credit for completion of the experiment. Participants provided informed consent prior to taking part in the experiment and reported normal or corrected-to-normal visual acuity and normal color vision. All procedures were approved by the Institutional Review Board.

During the experiment, 3 participants accidentally skipped through the second phase, so their test data was not included. Additionally, data was excluded from participants who drew fewer than 4 (n = 8) items and/or had baseline errors more than 2 standard deviations from the mean (n = 4). These exclusions left us with a final sample of 45 participants.

### Stimuli

The stimulus set for this experiment was created using images from previous recognition-induced forgetting studies (e.g., Maxcey, Dezso, et al., 2019; Maxcey, Janakiefski, et al., 2019). The set consisted of 64 objects total. There were eight exemplars from eight different categories (backpack, bowtie, chair, clock, hat, mug, pillow, plate). Images were 512x512 pixels and centered on an all-white background. In the first phase, participants were shown half of the objects (i.e., four from each category). The four images from each category shown in phase one were distinct from each other in both color and design, enabling scoring of recalled images in the second phase. All participants viewed the same 32 images in the first phase in random order. In the third phase, participants were shown all 64 images, again in random order.

**Procedure**

Participants were seated at a table with a computer. Researchers sat in the room during the experiment but were out of view from the subject.

As shown in Figure 1, our study included three phases, typical of induced forgetting studies: a study phase, a practice phase, and a test phase. In the study phase, participants were shown 32 objects on the screen, one at a time, for three seconds each. A 500 ms white screen with a fixation cross interleaved stimulus presentation. The 32 objects comprised half of the total stimulus set. Four distinct exemplars belonged to each of the eight categories. Images were only shown once during the study phase. Participants were instructed to closely study the visual details of the objects for a later memory test.

The second phase allowed participants to practice accessing their memory for a subset of the objects they were shown in the first phase. After the end of the first phase, participants were provided with 55 colored pencils, consisting of various shades of 10 different colors. Participants were also given four white pages with two blank boxes on each (see Fig. 1). Participants were prompted to draw any two objects from four of the eight categories (i.e., to draw eight objects total). The four categories were randomly selected for each trial and presented on the screen to the participant along with instructions. Then, participants labeled which category they were drawing on each page so that it would be clear to the scorer. Participants were told to draw one image in each blank box, but to leave any boxes blank if they could not recall an item.

Participants were instructed by the researcher to use color to denote the object they were drawing whenever possible. Sample instructions for one subject read: You will be drawing two of the pictures you saw in phase one from each of the following categories: bowtie, hat, mug, plate). At the top of each page, label the category you are drawing. If you cannot remember two objects for any of the categories, please leave the other spaces blank. Once you are done drawing your pictures to the best of your ability, raise your hand so your materials can be collected.

The test phase consisted of an old-new recognition judgment task. Participants were sequentially presented 64 objects and instructed to indicate whether that object was old (i.e., shown in phase one) or new. The 32 objects initially shown in the study phase elicited a correct response of old and 32 novel objects that the participant had not yet seen elicited a correct response of new.

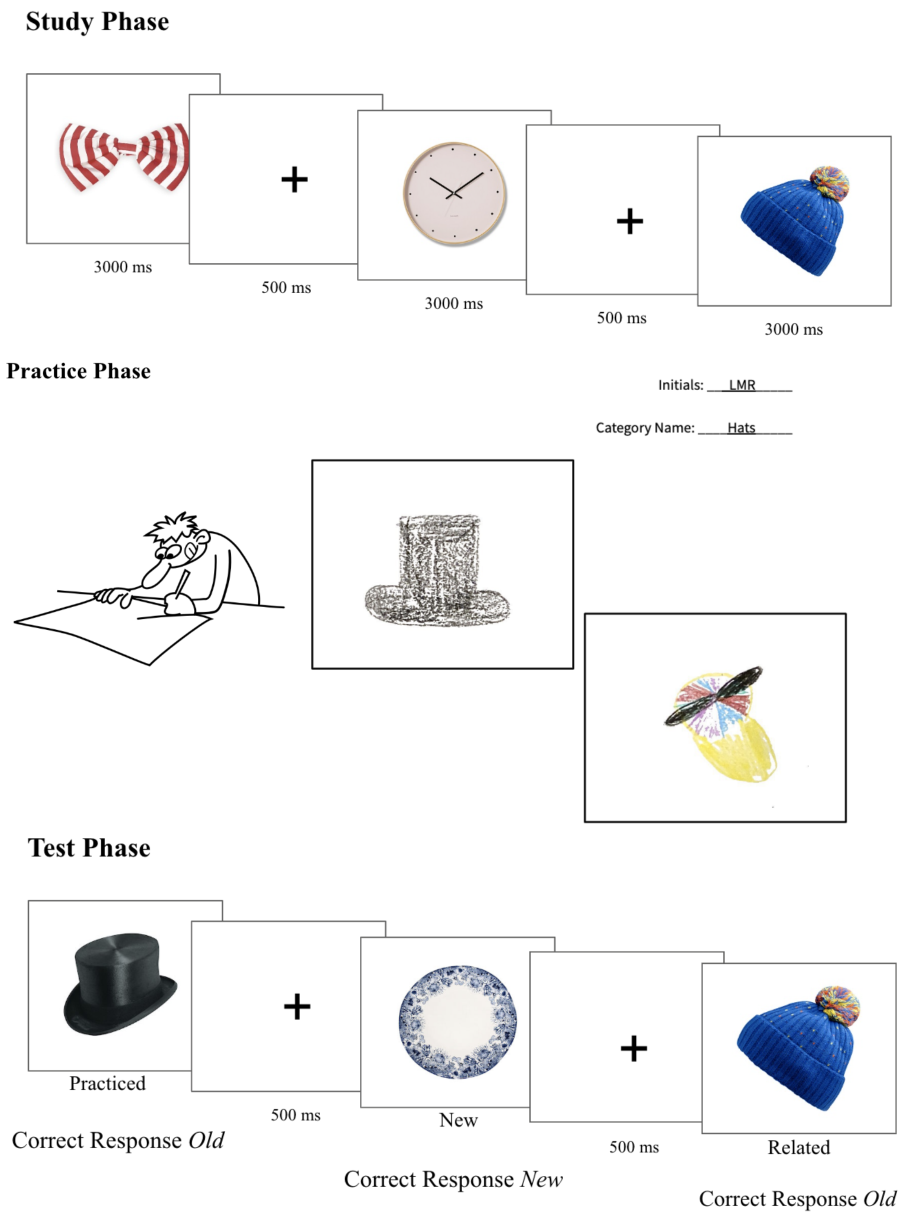
The studied objects fell into one of three categories: (1) baseline objects were the images shown in phase one, but not practiced (i.e., not drawn) in phase two, (2) practiced objects were those that the participant drew in the second phase (e.g., the black top hat in Fig. 1), and (3) related objects were those that belong to categories that were practiced in phase two, but were not practiced/drawn themselves (e.g., the blue winter hat in Fig. 1). Of the 32 new objects, 16 were from practiced categories and 16 were from non-practiced categories. Participants were given unlimited time to make each decision and were instructed that accuracy was more important than speed.

**Scoring**

The scorer used a combination of the drawing judgment and object (feature) selection methods, as shown in Figure 2, to determine whether a participant's drawing was a match to an image in the stimulus set. Drawings for this study were scored as correct if they matched the two distinct features- color and pattern- to a target stimulus. Categories with simple and easy to draw

**Figure 1**

*Three-Phase Induced Forgetting Paradigm*

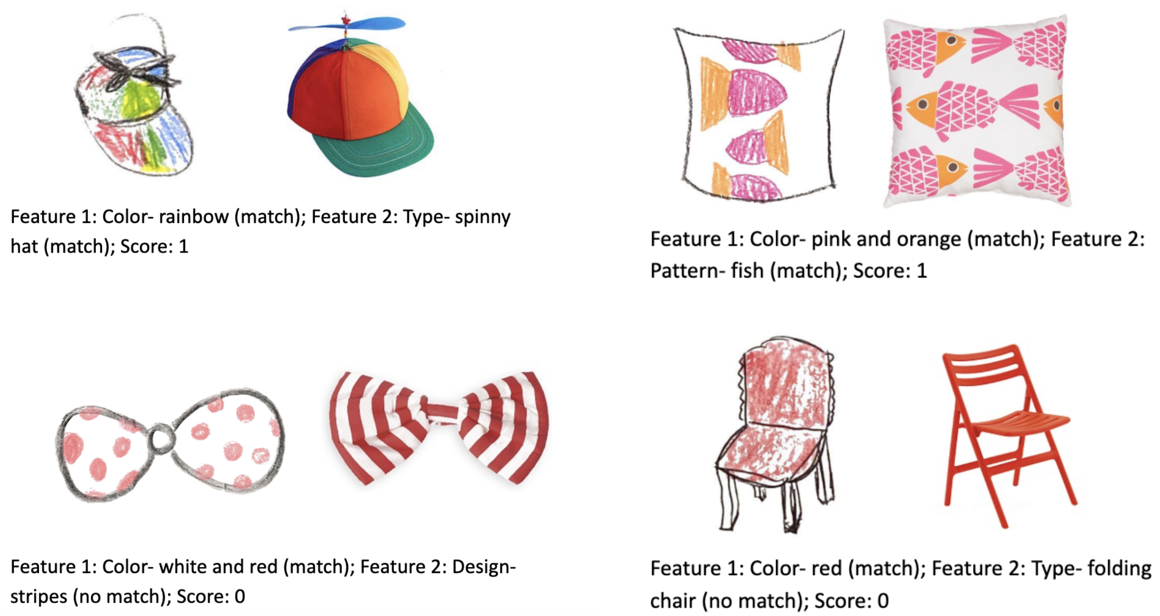



**Note:** Example of the stimuli and procedure. Study phase consisted of 32 images from eight categories, presented sequentially for 3 s each, with a 500 ms pause in between. For the practice phase, participants were given four categories of items from phase one and asked to draw two items per category. Test phase consisted of 64 images, 32 old and 32 new. Participants responded by button press to indicate whether an item was "old" (from phase one) or "new".

exemplars were chosen so that artistic ability would not interfere with participant performance. Because of the simplicity of the images, drawings were either scored as a correct (1) or incorrect (0) match, with no partial credit for ambiguous matches. For each category, “practiced” items refer to those images that participants accurately drew in the practice phase. The remaining items from that category, that the participant did not draw, were that participant’s “related” items. If recall-induced forgetting occurred, performance for practiced items would fall above baseline and performance for related items would fall below.

**Figure 2**

*Scoring Procedures*




**Note:** Example of the stimulus coding procedure. Each image from the study phase has two distinct features- color and type/design- and drawings needed to contain both features in order to be coded as a correct match. Correct matches become the practiced category for that participant. Items from practiced categories that were not drawn themselves become related items.

**Data Analysis**

The dependent variable for this experiment was percentage correct- accurate identification of “old” (baseline, related, practiced) and “new” items- on the memory task in the final phase. First, to determine whether practice improved the recognition of practiced items, we conducted a paired samples t-test comparing the average performance for practiced items and baseline items. Then, to see if practice impaired recognition for related items, we ran an additional paired samples t-test comparing accuracy for related items and baseline items. These t-tests included measures of Cohen’s d effect size, indicating the magnitude of the effect practice had on each item type. We used an alpha level of $p = 0.05$ to determine significance. We also calculated and report values of d’ for baseline, related, and practiced items to account for possible response bias. To avoid infinite values, we corrected 0’s and 1’s by adding 0.5 to all hits, 0.5 to all false alarms, and adding 1 to the total trial count for each participant (Hautus, 1995; Macmillan & Creelman, 2004; Miller, 1996). We then ran the same pre-planned t-tests on the d’ values to test for significant differences between baseline and practiced (i.e. the practice effect) and between baseline and related (i.e. the induced forgetting effect).

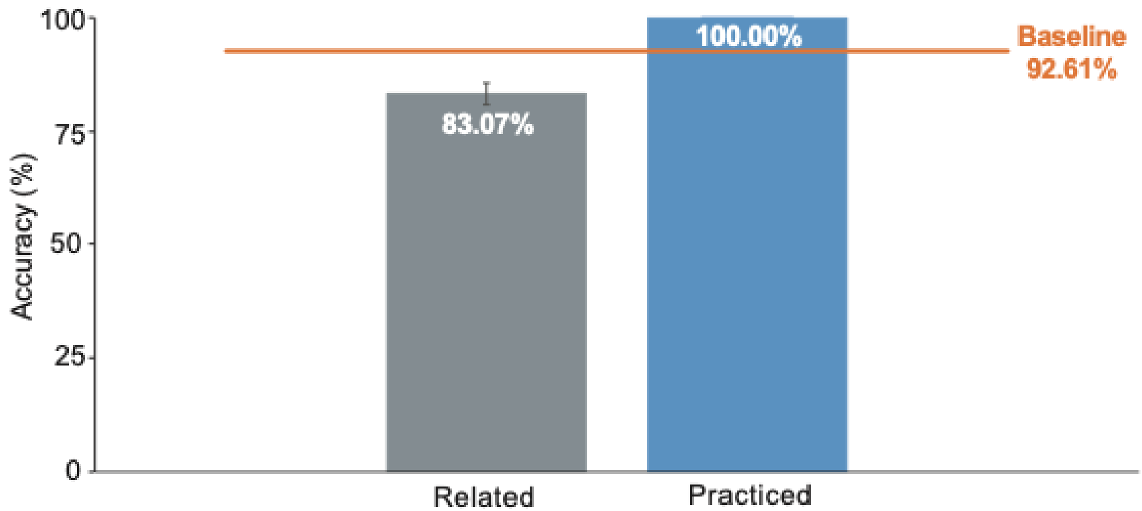
## Results

Figure 3 illustrates participant performance on the old-new recognition judgment task in the test phase. Mean accuracy across practiced and related items is compared to the mean accuracy for baseline items. As shown, participants’ memory for practiced items was high ($M$ = 100%, $SD$ = 0.00), reliably above memory for baseline items ($M$ = 92.61%, $SD$ = 7.33), demonstrating a positive effect of practice ($t(44) = 4.068$, $p < 0.001$, d = 0.606). Demonstrating induced forgetting, memory for related items ($M$ = 83.07%, $SD$ = 15.98) was hurt by practice, falling significantly below baseline ($t(44) = -6.76$, $p < 0.001$, d = -1.008).

Induced forgetting was also significant when measuring performance using d' values for related (*M* = 2.57, *SD* = 0.80) and baseline (*M* = 3.00, *SD* = 0.71) items ($t(44) = 3.422$, $p < 0.001$, d = 0.510). This suggests that the related errors were accounted for by actual forgetting,

**Figure 3**

*Memory for Performance by Stimulus Type*




**Note:** Accuracy of participant responses for the old-new recognition memory task in the test phase. Practiced objects (blue bar) are those objects the participants drew in the practice phase. Related objects (gray bar) are the remaining objects from practiced categories that were not drawn in the practice phase. Baseline objects belong to categories not prompted during the second phase. The error bars in this figure represent standard error (SE for practiced items = 0).

rather than response bias. There was not a significant difference between the d' values for practiced (*M* = 2.98, *SD* = 0.45) and baseline (*M* = 3.00, *SD* = 0.71) items ($t(44) = 1.611$, $p = 0.114$, d = 0.240). This could be a result of ceiling effects but is irrelevant to the question regarding the presence of induced forgetting. Induced forgetting, measured both in accuracy and d', found here is the first evidence of recall-induced forgetting of real-world objects, demonstrating that drawing is indeed an empirical means to quantify memory representations.

## Discussion

The drawing method implemented here successfully allowed us to empirically gauge memory for real-world pictures of everyday objects. Using this method, we demonstrated forgetting of previously studied objects induced by recall of categorically related real-world objects. Participants studied pictures of real-world objects, then used drawing to demonstrate that they recalled a cued subset of those objects in a second phase. In a third phase, participants completed an old-new recognition judgment task to probe memory for all objects. Subjects had the best memory for objects they recalled in the second phase (i.e., *practiced* objects), worse memory for categories of objects that were studied and never recalled (i.e., *baseline* objects), and even worse memory for objects that belonged to recalled categories but they themselves were not recalled (i.e., *related* objects). This pattern of findings demonstrates the hallmark induced forgetting result (baseline > related) and the hallmark practice effect (practiced > baseline), supporting our hypothesis that *recall*-induced forgetting operates over visual stimuli, not just verbal stimuli as previously shown (Maxcey, Janakiefski, et al., 2019).

### Induced Forgetting

To our knowledge, the present study was the first to use a free recall task when studying the recall-induced forgetting of real-world objects. A similar study found the retrieval-induced forgetting of visual information implemented novel shapes (Kovacs et al., 2022) rather than the real-world objects used herein. After studying the set of shapes, Kovacs et al. cued participants with the color and pattern of the target item during the practice phase. Participants were meant to draw the novel shape that corresponded to each cue given to them. The participants in the present study were provided with the names of four categories during the practice phase, but they received no cues on which items to practice for each category.

It is unclear whether this lack of experimental control over which items participants practice is a limitation of the current design. One may argue that participants are simply recalling and drawing the most memorable objects from the stimulus set, and that their worsened performance on related items was due to those items being less memorable, not due to induced forgetting. However, Bainbridge et al. (2019) found that the memorability of an object did not influence how likely that object was to be recalled, suggesting that participants were not more likely to access highly memorable objects over less memorable objects in the second phase. Still, future experiments may consider choosing objects of similar memorability when creating their stimulus set to eliminate this concern.

**Experimental Protocol**

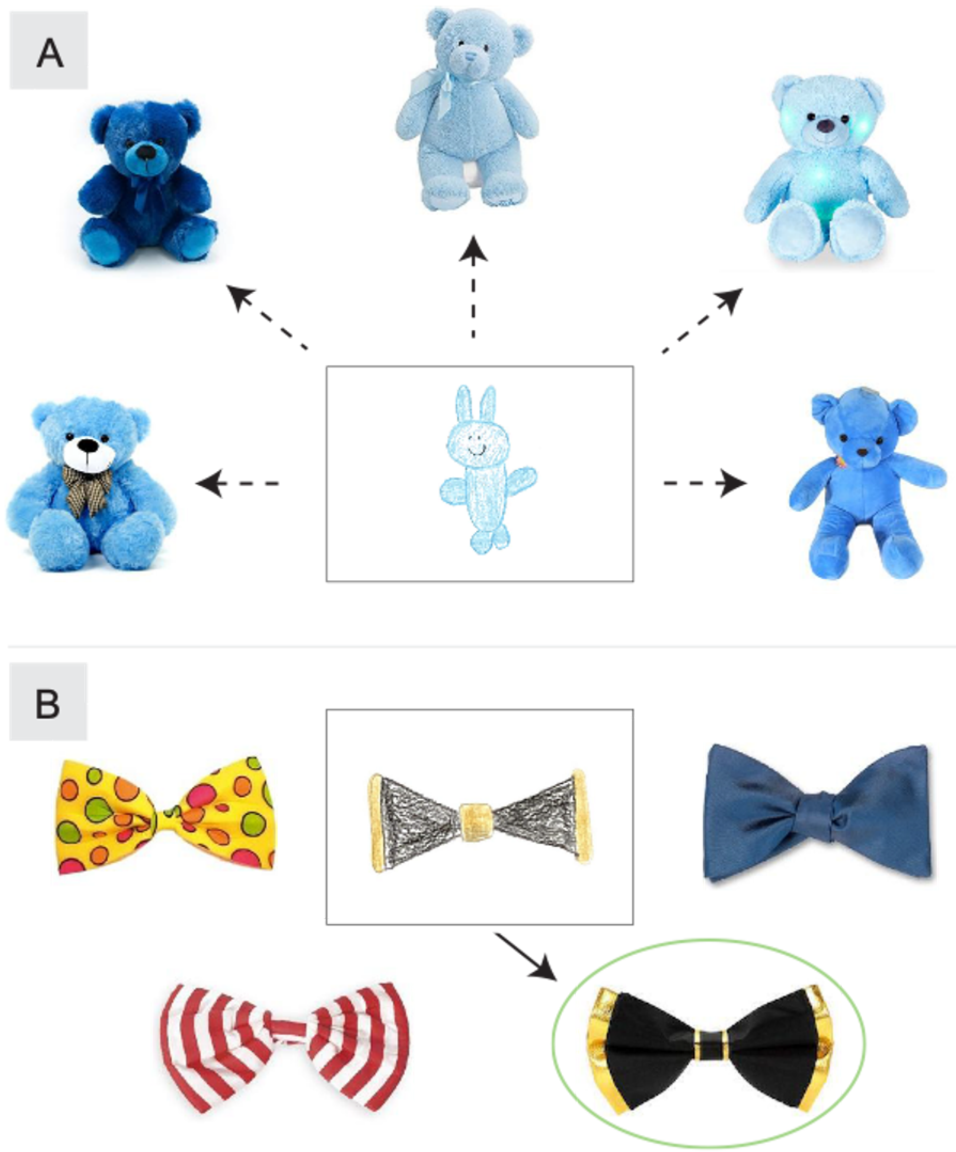
The present study expanded the pool of drawing methods that can be used to study memory of visual information. Previously developed drawing methods focused primarily on how to measure memory of scenes (e.g., Bainbridge, 2021). These scenes contain multiple objects, each with a unique spatial location, that can be used to quantify accuracy of the subject's recall. Here, we established a protocol for quantifying memories of individual objects through drawing recall. Individually drawn objects in the present study are more difficult to score relative to scenes because not only do they have less available attributes than a scene, the induced forgetting paradigm requires memory for multiple items from the same category. This requirement of differentiating drawings of four exemplars from the same category meant it was critical to consider how many object categories to include, which object categories to include, and how many exemplars for each category to include when designing our drawing study.

Stimulus selection was one of the most critical components in designing our study. The original stimulus set for this procedure had been borrowed from the Maxcey Memory Lab archives (e.g., Scotti e. al. 2020) and contained 864 images (54 for each of 16 categories). In many previous experiments using that stimulus set, the computer randomly selected 12 images from 12 of the categories to be included. The first modification we made to our procedure was a reduction in the number of categories. We eliminated certain categories, such as jackets, due to difficulty drawing their outlines, and other categories, such as teddy bears, whose exemplars were too similar and could not be distinguished from each other (see Fig. 4A). This reduced the original 16 categories to eight categories with exemplars possessing multiple features that could be clearly distinguished from each other. We then chose eight distinct images for each category and coded the experiment such that the same four would be shown to each participant during the study phase, and the remaining four would be novel images presented in the test phase.

The reduction in the stimulus set was made to make the drawing task easier for participants and the scoring objective. The original induced forgetting procedure showed participants 72 images in the study phase, then asked them to draw three images for six categories. We ran five pilot subjects at this size, and it was clear a modification was needed. Participants were not able to freely recall 18 images, and the drawings they could provide were difficult to score (see Fig. 4A). The current procedure requires participants to recall and draw eight images total, two each from four categories. This task has shown more feasible for participants and those tasked with scoring. With the change in set size and procedure, participants were shown the same four images for each category in the study phase, so each drawing could only be one of four objects (see Fig. 4B). Simple, pre-planned scoring procedures were essential to the success of this study, because without knowing which items a participant practices, it would have been impossible to determine whether induced forgetting had occurred.

**Figure 4**

*Comparison of Scoring Procedures*




**Note: A.** Example of a scoring task from a pilot trial. The participant drew a blue teddy bear, but did not include distinguishable features. With multiple blue bears in the stimulus set, it was impossible for scorers to determine which image the participant meant to draw and thus which item to score as practiced. **B.** Example of the updated procedure. The participant drew a black bowtie with gold accents. There was only one image from the stimulus set that matched these features, so scorers easily identified this image was practiced.

That is, the related objects could differ by subject, depending on which half of the category was drawn (i.e. practiced).

*Future Directions*

The present study used a recall task in the practice phase, then tested participants' memory with a recognition test. Now that the present study demonstrates proof of concept for drawing, further research on induced forgetting may consider using recall tasks in the test phase as well. Researchers could use cued recall (e.g., draw the bowtie with polka dots) to test for memories of specific item types, or free recall (e.g., draw as many bowties as you remember) to test for overall retention of the set. Knowing that recall is a more difficult task than recognition (Cabeza et al., 1967), having participants draw in the test phase may reveal an even more significant forgetting effect.

*Drawing Expertise*

Given the success of drawing to assess memory among a general undergraduate population, future research may develop a protocol using a sample of artists. In the induced forgetting paradigm, it is likely that a recall task would be much simpler for drawing experts, allowing experimenters to gauge whether forgetting inversely tracks recall effort.

In addition, testing artists may be especially useful when applying drawing methods to other experimental protocols. As previously mentioned, here we made significant reductions and changes to our stimulus set to accommodate our participants not being artistically talented. Using a sample of artists eliminates this challenge and would allow for the testing of a broader stimulus set. Recent evidence suggests that artists do indeed produce better drawings from memory that are more similar to the original image (Dechterenko, 2023). As drawing becomes a more popular method of accessing and studying visual memory, the images that artists can create may become an invaluable resource to the study of memory.

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