SHORT REPORT

# Recognition-induced forgetting is caused by episodic, not semantic, memory retrieval tasks

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## Abstract

Recognition-induced forgetting is a within-category forgetting effect that results from accessing memory representations. Advantages of this paradigm include the possibility of testing the memory of young children using visual objects before they can read, the testing of multiple types of stimuli, and use with animal models. Yet it is unknown whether just episodic memory tasks (Have you seen this before?) or also semantic memory tasks (Is this bigger than a loaf of bread?) will lead to this forgetting effect. This distinction will be critical in establishing a model of recognition-induced forgetting. Here, we implemented a design in which both these tasks were used in the same experiment to determine which was leading to recognition-induced forgetting. We found that episodic memory tasks, but not semantic memory tasks, created within-category forgetting. These results show that the difference-of-Gaussian forgetting function of recognition-induced forgetting is triggered by episodic memory tasks and is not driven by the same underlying memory signal as semantic memory.

**Keywords** Recognition-induced forgetting · Retrieval-induced forgetting · Long-term memory · Visual long-term memory · Forgetting · Semantic memory · Episodic memory

## Introduction

Information in memory may be stored in associated networks (e.g., Raaijmakers & Shiffrin, 1981) such that accessing one item stored in memory can affect other information stored in memory. These relationships can be seen playing out in recognition-induced forgetting (Maxcey & Woodman, 2014), where accessing one item in memory (e.g., a blue mug) leads to the forgetting of related memories (e.g., other mugs stored in memory). Figure 1 shows the activation pulse that results from memory access, taking a difference-of-Gaussian shape. There is a benefit in memory (i.e., peak) for the accessed object, called the *practice benefit*, and within-category forgetting

(i.e., surrounding suppression), the latter of which is the signature of *recognition-induced forgetting* (Maxcey, Janakiefski, Megla, Smerdell, & Stallkamp, 2019).

Recognition-induced forgetting (Maxcey & Woodman, 2014) is similar to *retrieval-induced forgetting* (Anderson, Bjork, & Bjork, 1994), which employs a recall task rather than a recognition task to cause forgetting. A common approach in theories of memory is to assume recall and recognition are different retrieval processes applied to the same memory trace (Gillund & Shiffrin, 1984; Humphreys, Bain, & Pike, 1989; Murdock, 1982), meaning both induced forgetting effects are *retrieval*-induced forgetting effects. The term *recognition-induced forgetting* specifically describes the task that induces forgetting, whereas the term *retrieval-induced forgetting* more broadly describes the memory stage in which forgetting occurs (for a review of retrieval-induced forgetting, see Murayama, Miyatsu, Buchli, & Storm, 2014).

The typical recognition-induced forgetting paradigm consists of three phases: a study phase, practice phase, and test phase. In the study phase, subjects are instructed to memorize the details of sequentially presented objects for a later memory task. The objects include multiple images from the same object category (e.g., six different scarves, six different chairs). Then in the practice phase, subjects complete an old–new recognition task in response to a subset of the stimuli from

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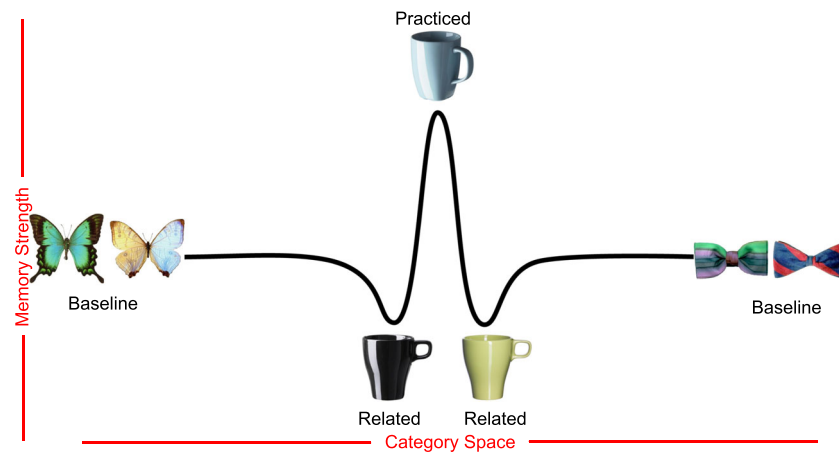
**Fig. 1** Activation pulse triggered by accessing an object held in long-term memory. The peak in memory activation for the recognized item is the practice benefit, and the surrounding suppression for the within-category items is the signature of recognition-induced forgetting

the study phase and an equal number of novel objects drawn from corresponding categories.

The practice phase creates three classes of objects that are analyzed at test. *Practiced* objects are presented once during the study phase and then twice in the practice phase. At test subjects have previously seen these objects three times during the experiment. *Related* objects are presented once during the study phase and not during the practice phase. The name for these objects, *related*, describes the relationship between these objects and practiced objects. Related objects are drawn from the same category as practiced objects (e.g., vases), but related objects are not practiced. *Baseline* objects are shown once during the study phase and not in the practiced phase. They provide a baseline measurement for memory because, unlike related objects, their entire category was not involved in practice (e.g., none of the mugs were practiced; see Fig. 1).

Finally, in the test phase, subjects again complete an old–new recognition judgment task, this time in response to a larger set of stimuli from the study phase. Memory for the three object types (i.e., practiced, related, and baseline) from this test phase is analyzed to determine whether there is a benefit of practice and recognition-induced forgetting is present. Recognition-induced forgetting is present when memory for related objects is significantly worse than memory for baseline objects (Maxcey & Woodman, 2014).

Recognition-induced forgetting is not due to within-category interference (Maxcey, 2016), operates over some objects of expertise, such as White faces (Rugo, Tamler, Woodman, & Maxcey, 2017), is present in young children (Maxcey & Bostic, 2015) and older adults (Maxcey, Bostic, & Maldonado, 2016), and persists despite awareness of the effect and instruction to resist forgetting (Maxcey, Dezso, Megla, & Schneider, 2019). Previously, we have found that recognition-induced forgetting did not operate over temporally grouped objects and concluded

that episodic memories were immune to this type of forgetting (Maxcey, Glenn, & Stansberry, 2018). However, more recently we have shown that the reason we did not find recognition-induced forgetting for temporally grouped objects was the strength of thematically grouped objects (Scotti, Janakiefski, & Maxcey, 2020). Specifically, thematically grouped objects are susceptible to recognition-induced forgetting provided that the association among objects is moderately strong. Therefore, it appears that recognition-induced forgetting may operate over episodic memory representations under certain conditions. Although our previous work has found evidence on both sides of the episodic versus semantic memory issue, in the present study, we definitively pit semantic and episodic memory tasks against one another.

## The present study

Just as drawing a distinction between episodic and semantic memory retrieval has proven useful in determining their underlying neural mechanisms (Wiggs, Weisberg, & Martin, 1998), here, we ask over which of these two memory systems recognition-induced forgetting operates. This distinction will be critical in establishing a model of recognition-induced forgetting. To this end, we capitalized on semantic and episodic memory retrieval tasks (see Fig. 2) to determine which induces forgetting. As shown in Fig. 2, the nature of a semantic memory task is that it activates the meaning of an object (e.g., the size of an object or what one would do with an object). The nature of an episodic memory task is that it activates encountered memory representations. For example, the old–new recognition judgment task shown in Fig. 2, where subjects are asked whether they have ever seen this specific butterfly before, requires the subjects to access their memory representations for recently encountered butterflies. We modified the recognition-induced forgetting paradigm to
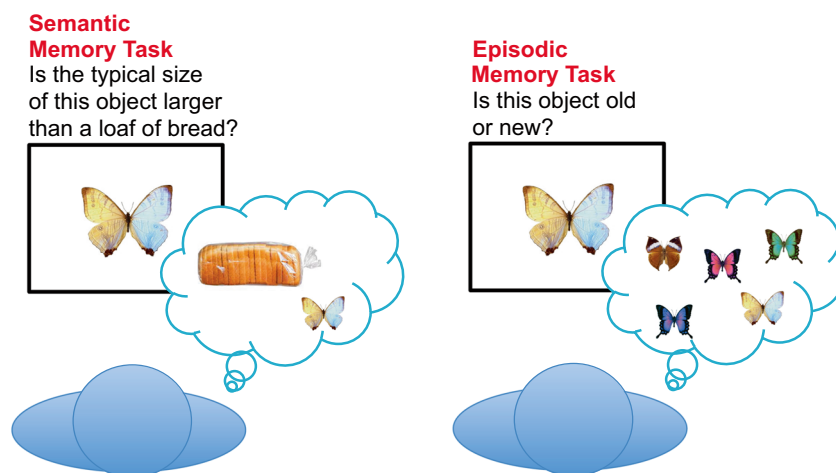
**Fig. 2.** Example of semantic and episodic memory tasks. The semantic memory task probes semantic memory, and the episodic memory task probes episodic memory

include tasks that activate both semantic and episodic memory for the same subject in separate phases. This design allows us to independently measure the activation of episodic and semantic memory in recognition-induced forgetting within the same subjects, definitively concluding which types of memory tasks cause this type of forgetting.

## Hypothesis

Our hypothesis is that the difference-of-Gaussian forgetting function of recognition-induced forgetting is triggered by episodic memory tasks and is not driven by the same underlying memory signal as is semantic memory. In this way, recognition-induced forgetting serves remembering by suppressing competitors.

## Predictions

As shown in Fig. 2, a semantic memory task does not involve within-category competitors, so there would be no need for within-category suppression. However, the episodic memory task does involve within-category competitors (e.g., determining if you've seen this butterfly involves the activation of multiple memory representations of butterflies), hence the need for suppression to serve remembering, and the resulting recognition-induced forgetting.

Forgetting in a recognition-induced forgetting paradigm occurs in the second phase—it is the task in this phase that induces the forgetting. By replacing the characteristic episodic memory task in the second phase with a semantic memory task, we can then measure whether recognition-induced forgetting persists using the typical measurements of overall hit rate between baseline and related objects at test. If semantic memory tasks lead to forgetting, then recognition-induced forgetting will persist.

Because of the nature of the design of the experiment, the test phase returns to an episodic memory task. This design allows us to include both a semantic memory task and an episodic memory task in the same experiment, for every subject. Therefore, even in the absence of an overall effect of recognition-induced forgetting, we can confirm that this episodic memory task induced within-category forgetting by analyzing whether forgetting unfolds across the test phase. If encountering objects from the same category in an episodic memory task induced forgetting, then split-half analyses on memory for each category in the test phase should show better memory for the first half of old objects in each category encountered by the subject in the test phase than for the second half.

## General methods

All experiments were minor modifications of the recognition-induced forgetting paradigm described here (see Fig. 3). In the first phase, the study phase, 72 objects were sequentially presented for 5 seconds each, interleaved by a 500-ms fixation cross. Subjects were instructed to memorize the objects for a later memory test. The 72 objects were randomly drawn from 12 categories (e.g., gloves, butterflies) with six exemplars in each category (e.g., six different gloves, six different butterflies). Then, subjects completed a visual distractor task (i.e., Where's Waldo search) during a 5-minute delay before the next phase. The second phase, the practice phase, required subjects to complete a semantic judgment task in response to a subset of studied objects and an equivalent number of novel objects drawn from the same semantic categories. In Experiment 1, the semantic judgment was a wear/no-wear task (i.e., Is this an object you would wear on your body?). In Experiment 2, the semantic judgment was a size judgment task (i.e., Is this object larger
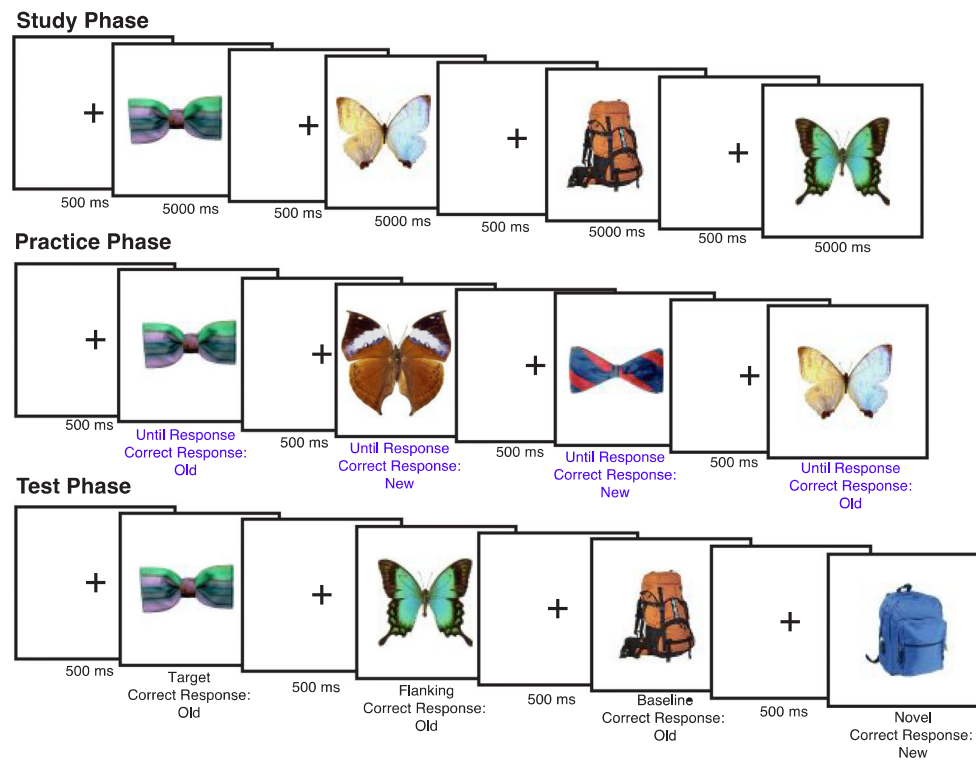
**Study Phase**

**Practice Phase**

**Test Phase**

**Fig. 3** General methods. In the study phase, subjects fixated a central fixation point for 500 ms, followed by the presentation of the object for 5,000 ms, until all objects were randomly presented. The subjects were instructed to remember each item for a later memory test. The study phase was followed by a 5-minute visual distractor task. In the second phase, half of the items from half of the categories were again presented along with an equal number of novel items. The subject's task differed depending on experiment. In typical recognition-induced forgetting studies during this phase, subjects engaged in recognition practice by completing an old–new recognition judgment task in response to each object. In Experiment 1, subjects completed a wear/no-wear judgment task. In Experiment 2, subjects completed a size judgment task. Each old object was practiced on two practice trials. The practice lures were items drawn from the same categories as the practice items. The second phase was again followed by a 5-minute visual distractor task. The test phase probed memory for objects via an old–new recognition judgment task

than a loaf of bread?). The specific old objects that were practiced were a counterbalanced selection of half the objects (three) from half the categories (six), totaling 18 practiced objects. Old objects were each practiced twice, across 36 trials. The remaining 36 trials consisted of six new objects[1] from the same six practiced categories, totaling 72 practice trials. The practice phase was followed by another 5-minute visual distractor task. The third phase, the test phase, was also an old–new recognition judgment task. The test phase consisted of 72 trials with 36 old objects and 36 new objects. The old objects included two practiced objects and two related objects from each practiced category and two baseline objects from each nonpracticed category.

## Data analysis

The primary dependent variable for recognition memory is hit rate across the three main object types: practiced, related, and baseline. To provide converging evidence for hit rate analyses, we also report the discrimination measure, $Pr$, and the associated bias measure, $Br$[2] (Feenan & Snodgrass, 1990). All preplanned $t$ tests are accompanied by scaled JZS Bayes factor to quantify support for the null or alternative hypothesis (Rouder, Speckman, Sun, Morey, & Iverson, 2009). Significant $t$ tests are also accompanied by Cohen's $d$ measure of effect size.

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[1] This design is typical of the practice phase in recognition-induced forgetting studies, where old objects are practiced twice during the study phase and new objects are not repeated while subjects are engaged in an old–new recognition judgment task. If new objects were repeated, on the second trial the correct response would be "old."

[2] The method suggested by Feenan and Snodgrass (1990) was used to calculate both $Pr$ and $Br$ involving $H$ and $FA$. $Br$ values greater than .5 are indicative of a liberal bias, whereas values lower than .5 indicate a conservative bias. When calculating $Br$, $Pr$ values of 1 were changed to .99. Please see Ian Neath's useful website for more information (https://memory.psych.mun.ca/models/recognition/index.shtml).

## Power calculation

Pilot experiments run to determine the necessary sample size (Faul, Erdfelder, Lang, & Buchner, 2007) had a $d_z = .76$. If we wanted to have 95% power to detect an effect equal to this with a two-tailed $t$ test, we would require 25 subjects per condition. We ran 44 subjects knowing that some experiments may show a null result (i.e., the absence of recognition-induced forgetting indicated by no reliable difference between baseline and related objects).

## Experiment 1

In Experiment 1, the old–new recognition judgment task typical of the practice phase was replaced with a wear/no-wear judgment task, similar to the categorization tasks employed in negative priming experiments, to determine whether recognition-induced forgetting occurred.

## Method

### Participants

Subjects were a new group of 44 The Ohio State University undergraduates (mean age of 19.3 years, 23 females, 17 males) who completed the experiment in exchange for course credit.

### Procedure

The procedure was identical to the General Procedure outlined above, with the following exceptions. The 12 object categories were apple, backpack, chair, watch, glove, basket, bowtie, butterfly, fan, scarf, plane, and jacket. The old–new recognition judgment task of the practice phase was replaced with a wear/no-wear judgment task in which subjects were asked to respond whether or not each object was an item a person would typically wear on their body. The correct answer was that the backpack, bowtie, watch, glove, scarf, and jacket object categories would typically be worn and the apple, chair, fan, basket, butterfly, and plane object categories would not be typically worn.

## Results

Given that the question of Experiment 1 was whether a semantic judgment task led to recognition-induced forgetting, memory as measured by hit rate across object types in the test phase is the critical dependent variable in Experiment 1.

Average hit rates across the three object types at test are shown in Fig. 4a, with memory for baseline objects indicated by the x-axis. There is a reliable benefit for
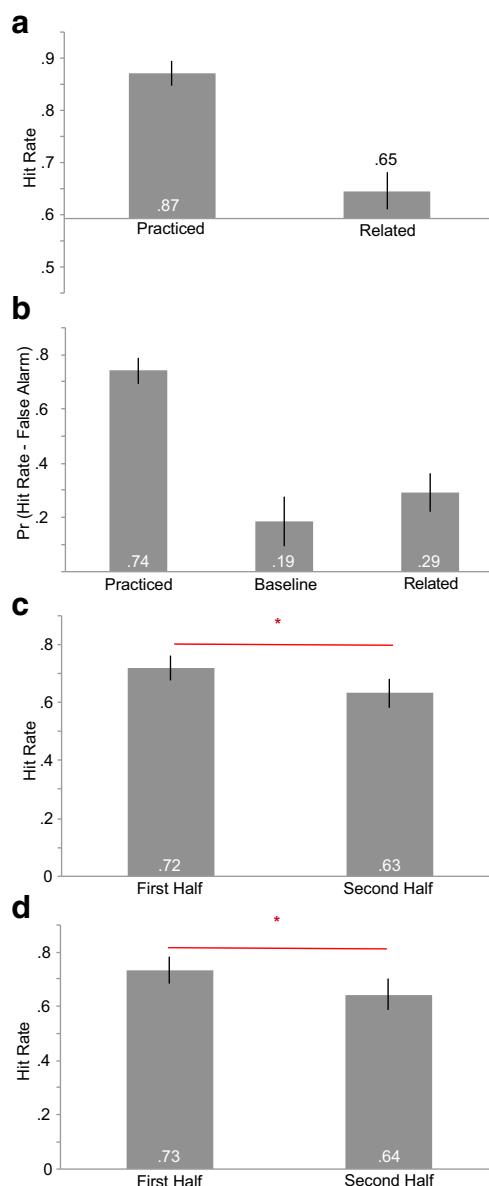


**Fig. 4** **a** Hit rate for old objects in the test phase across object type from Experiment 1. Memory for baseline objects indicated by the x-axis. **b** $Pr$ for old objects in the test phase across object type. **c** Hit rates for the first and second half of old objects at test collapsed across object types. **d** Hit rates from 44 recognition practice participants in Experiment 1, Maxcey, Janakiefski, et al. (2019). All error bars represent 95% confidence intervals as described by Cousineau (2005) with Morey's (2008) correction applied

memory for practiced objects (.87) relative to memory for baseline objects (.59), $t(43) = 8.749$, $p < .001$, $JZS_{ALT} = 190,235,588$. The reliable benefit of practice replicates when using $Pr$ (see Fig. 4b), with baseline $Pr$ (.19) reliably lower than practice $Pr$ (.74), $t(43) = 8.752$, $p < .001$, $JZS_{ALT} = 191,952,507$. However, the signature of recognition-induced forgetting is absent. Specifically, when subjects engaged in an object categorization task,

memory for related objects (.65) was actually higher than memory for baseline objects (.59), $t(43) = 1.709$, $p = .095$, $JZS_{NULL} = 1.606$, a nonsignificant trend in the opposite direction predicted by recognition-induced forgetting. The absence of recognition-induced forgetting replicates when using $Pr$ (see Fig. 4b), with baseline $Pr$ (.19) trending in the opposite direction from related $Pr$ (.29) predicted by recognition-induced forgetting, $t(43) = 1.719$, $p = .093$, scaled $JZS_{NULL} = 1.57$, and neutral biases for both baseline ($Br = .48$) and related ($Br = .5$).

### Split-half analysis

If the reason forgetting did not occur was due to the nature of the task in the second phase, then returning to an old–new recognition judgment task in the test phase should begin to cause forgetting that can be seen within each category. To confirm that returning to an old–new recognition judgment task typical of this paradigm would result in forgetting, we conducted a split half analysis of hit rates across the test phase within each category. This is shown in Fig. 4c, where memory for the first half of old objects in each category are plotted separately from the second half of old objects from each category. For example, if old bowties were presented on four trials throughout the test phase, then average memory accuracy to the first two encountered by the subject (i.e., "first half") should be better remembered than the average memory accuracy to third and fourth bowties encountered (i.e., "second half"). If forgetting of objects occurs as a consequence of activating memories in the same category to respond to an old–new recognition judgment task, this forgetting should emerge in the split-half analyses as better memory in the first half and worse memory in the second half. We found that memory for the first half of old objects in each category probed in the test phase (.72) was superior to memory accuracy during the second half of testing (.63), $t(43) = 3.43$, $p = .001$, $d = .54$, $JZS_{ALT} = 22.80$. This confirms that within-category forgetting, the signature of recognition-induced forgetting was unfolding over the test phase upon the return to the episodic old–new recognition judgment task. This split-half analysis results in the same reliable forgetting across the test phase when the traditional episodic task is employed during practice (see Fig. 4d for a previously unpublished split-half analysis of Experiment 1, picture recognition practiced condition; Maxcey, Janakiefski, et al., 2019). These analyses show that recognition-induced forgetting compounds across time scales in an old–new recognition judgment task.

### Discussion

Replacing the old–new recognition judgment task in the recognition practice phase, which induces forgetting in the typical recognition-induced forgetting paradigm, with a semantic

judgment task did not lead to recognition-induced forgetting. These results show that a semantic judgment task does not result in recognition-induced forgetting. Further, the split-half analysis demonstrates that forgetting unfolds across the test phase upon returning to an episodic memory task.

The nonsignificant enhancement in performance for related objects relative to baseline at test may be due to activating the general category to respond. Here, there was no need to suppress other members of the category, resulting in both the cost to related objects disappearing and a slight benefit to activating a category during the second phase in the absence of suppression.

The elimination of recognition-induced forgetting is not the result of changes in task between the practice and test phase (i.e., a context change) for three main reasons. First, we have previously modified the second phase by implementing a restudy phase in the second phase, and recognition-induced forgetting persisted (Maxcey, Janakiefski, et al., 2019). Second, changes to context between phases do not eliminate recognition-induced forgetting (Maxcey, 2019). Third, recognition-induced forgetting is an extremely robust effect (Maxcey, Dezso, et al., 2019), making it unlikely that a change to the task alone is responsible for eliminating the forgetting effect.

## Experiment 2

To replicate and extend the findings from Experiment 1, we replaced the second phase with a different type of semantic judgment task. In the second phase subjects completed a size judgment in which they reported whether each presented item was bigger than a loaf of bread.

### Method

#### Participants

Subjects were 44 The Ohio State University undergraduates (mean age of 20.3 years, 29 females, 11 males) who completed the experiment in exchange for course credit.

#### Procedure

The procedure was identical to Experiment 1, except that in the practice phase, subjects were asked whether the typical size of each object was bigger than a loaf of bread. The correct answer was that the apple, bowtie, watch, glove, scarf, and butterfly object categories would typically not be larger than a loaf of bread and the backpack, chair, fan, basket, jacket, and plane object categories would typically be larger than a loaf of bread.
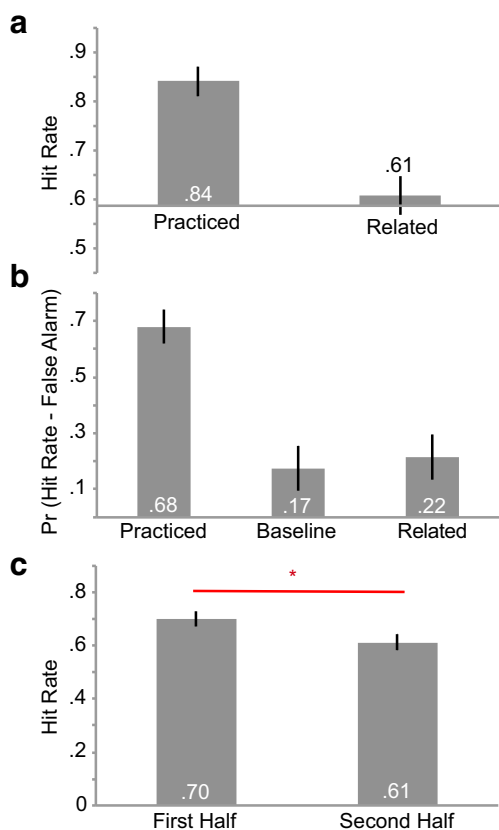
**Fig. 5** **a** Hit rate for old objects in the test phase across object type from Experiment 2. Memory for baseline objects indicated by the *x*-axis. **b** *Pr* for old objects in the test phase across object type. **c** Hit rates for the first and second half of old objects at test collapsed across object types. All error bars represent 95% confidence intervals as described by Cousineau (2005) with Morey's (2008) correction applied

## Results

Average hit rates across the three object types at test are displayed in Fig. 5a, with memory for baseline objects indicated by the *x*-axis. There is a reliable benefit for memory for practiced objects (.84) relative to memory for baseline objects (.59), $t(43) = 7.807$, $p < .001$, $JZS_{ALT} = 10,897,416$. The reliable benefit of practice is replicated when using *Pr* (see Fig. 5b), with baseline *Pr* (.17) reliably lower than practiced *Pr* (.68), $t(43) = 7.809$, $p < .001$, $JZS_{ALT} = 10,964,576$. However, the signature of recognition-induced forgetting is absent. Specifically, when subjects engaged in an object categorization task, memory for related objects (.61) was actually higher than memory for baseline objects (.59), $t(43) = .761$, $p = .451$, $JZS_{NULL} = 4.67$, a nonsignificant trend in the opposite direction predicted by recognition-induced forgetting. The absence of recognition-induced forgetting replicates when using *Pr* (see Fig. 5b), with baseline *Pr* (.17) trending in the opposite direction from related *Pr* (.22) predicted by recognition-induced forgetting, $t(43) = 0.761$, $p = .451$, scaled $JZS_{NULL} = 5.56$, and neutral biases for both baseline ($Br = .5$) and related ($Br = .5$). Replicating Experiment 2, in the split-half

analysis (see Fig. 5c) memory for the first half of old objects in each category probed in the test phase (.70) was superior to memory accuracy during the second half of testing (.61), $t(43) = 3.18$, $p = .003$, $d = .56$, $JZS_{ALT} = 12.17$.

## Discussion

Replicating and extending Experiment 1, a size judgment task did not lead to recognition-induced forgetting, but within-category forgetting began to unfold across the test phase upon returning to an episodic memory task. Combined with Experiment 1, these results demonstrate that a semantic judgment task does not induce within-category forgetting, but forgetting compounds across time in an episodic memory task.

## General discussion

Here, we asked whether recognition-induced forgetting is driven by semantic or episodic memory tasks. To this end, we modified the recognition-induced forgetting paradigm to include both a semantic judgment task and an episodic memory task. We found that when the typical old–new recognition judgment task of the recognition-induced forgetting practice phase was replaced with semantic judgment task, forgetting did not occur. When subjects returned to an old–new recognition judgment task in the test phase, within-category forgetting did unfold across the test phase, as exemplars from the same category were encountered. These results demonstrate that tasks activating episodic memory, rather than semantic memory, induce forgetting. Specifically, each time we engage in a task that requires episodic memory (e.g., search memory for an encountered object stored in visual long-term memory or study an object for a later memory test), that event inhibits the most potent memory competitors (i.e., representations of objects in that same category). However, when subjects are given a task that involves semantic rather than episodic memory, such as to determine whether the pictured object is bigger than a loaf of bread, this forgetting did not occur. Taken together, these results demonstrate that the difference-of-Gaussian forgetting function of recognition-induced forgetting is not driven by the same underlying memory signal as semantic memory and compounds across time scales, halting only in the face of a task that involves semantic rather than episodic memory.

One may argue that the semantic task does not induce forgetting, because it is a less difficult task relative to the episodic recognition memory task typically employed in this paradigm, potentially not even activating semantic memory, and operating at a more shallow level of processing than the recognition task. This is unlikely to be the case, according to both the semantic memory literature and the levels of processing literature. First, according to the classic semantic memory work by Collins and Quillian (1969), making a judgment about an object, such as

determining whether a fact about an object is true (e.g., a shark has gills, a canary can fly) requires retrieval from semantic long-term memory. Therefore, the present study employs precisely a task mimicking classic examples of activating semantic memory. Second, in the levels of processing approach, the semantic level of processing is considered the deepest level that results in the strongest level of encoding (Craik & Lockhart, 1972). In fact, Craik and Lockhart (1972) specifically stated, "Depth implies a greater degree of semantic or cognitive analysis, p 675." Therefore, the semantic memory task employed here both activates semantic memory and involves a deep level of processing. Nevertheless, while the logic employed here is rooted in a rich history of literature, exploring the exact type of semantic retrieval that does or does not induce forgetting remains an open question.

Finally, one lingering concern may be that the semantic judgment does not constitute memory retrieval per se because the lures were not previously studied items. This concern stems from the argument that making a judgment about a novel object drawn from the same category as an item held in memory does not technically constitute memory retrieval. While it is true that half the objects in both the practice and test phases are novel objects, this aspect of the design does not affect the conclusion that semantic memory tasks do not lead to forgetting for two reasons. First, the practice and test lures are not previously studied items regardless of task—they are novel objects in both the semantic and episodic memory tasks. Therefore, any difference between tasks cannot be attributed to making judgments about novel objects. Second, we have recently demonstrated that correct rejections lead to recognition-induced forgetting, meaning that presenting old items for the subject to retrieve from memory is not required to induce forgetting (Fukuda, Pall, Chen, & Maxcey, 2020).

Recognition-induced forgetting studies do not instruct subjects to group the objects by categories. Nevertheless, subjects must be grouping objects into object categories (e.g., butterflies, bowties) or there would be no category over which within-category forgetting could operate (i.e., no recognition-induced forgetting). If subjects are grouping objects into semantic categories (Scotti et al., 2020), the present results, in which semantic tasks do not invoke forgetting, is surprising. However, subjects may be grouping objects based on perceptual similarity (e.g., all butterflies have similar defining perceptual features, which are separate from other objects like bowties). In this case, evidence that forgetting is driven by episodic memory tasks would not be as surprising. Ongoing work in our lab (Scotti, Maxcey, & McCann, 2019) is examining this question.

**Open Practices Statement** Reasonable efforts will be made to share the data and materials for the experiments reported here upon request. None of the experiments was preregistered.

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