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BRIEF REPORT

Recognition and rejection each induce forgetting

Keisuke Fukuda[1,2] · Shawal Pall[3] · Erica Chen[4] · Ashleigh M. Maxcey[5]

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Abstract
Recognition-induced forgetting, whereby the recognition of targeted memories induces the forgetting of related memories, results from the recognition of old objects and rejection of new objects. Here we asked whether both these tasks are necessary to induce forgetting. Our unique design allowed us to isolate the recognition of old objects from the rejection of new objects by presenting subjects with only new objects, only old objects, and a mixture of both in separate conditions of an old–new recognition task. In all three conditions, we successfully induced forgetting. The magnitude of forgetting was statistically indistinguishable across all three conditions, showing that recognition of old objects and rejection of new objects are each building blocks of forgetting. These findings pinpoint both recognition and rejection as mechanisms underlying recognition-induced forgetting and demonstrate the ubiquity of this forgetting effect.

Keywords Retrieval-induced forgetting · Recognition-induced forgetting · Long-term memory · Recognition memory · Visual long-term memory

Introduction

The massive capacity of the human long-term memory system may maintain its efficiency through forgetting (Anderson, 2003; Kim, Lewis-Peacock, Norman, & Turk-Browne, 2014). What induces this forgetting? In the recognition-induced forgetting paradigm, both recognizing old objects and rejecting new objects were combined, triggering the forgetting of related memories (Maxcey & Woodman, 2014). Here, we parsed apart the two tasks, recognition and rejection, and asked whether they were individually sufficient to induce forgetting. To this end, we parametrically manipulated the proportion of old items within subjects in the recognition practice phase of the recognition-induced forgetting paradigm (Maxcey & Woodman, 2014). In the critical conditions, the old–new recognition judgment task consisted of all-new objects (the *all-new* condition, testing whether rejection of new objects induced forgetting) and all-old objects (the *all-old* condition, testing whether recognition of old objects induced forgetting). In the control condition the old–new recognition judgment task was composed of 50/50 old–new objects (hence the name the *mixed* condition), replicating the standard paradigm. This modified recognition-induced forgetting paradigm uniquely allowed us to separately measure the impact that recognition and rejection have on forgetting within subjects. If recognition of old objects leads to forgetting, then recognition-induced forgetting will occur when all objects were old (Maxcey, Janakiefski, Megla, Smerdell, & Stallkamp, 2019b). If rejection of new objects leads to forgetting, then recognition-induced forgetting will occur when all items were new (Storm, Bjork, Bjork, & Nestojko, 2006). We predicted forgetting would occur when recognition and rejection were combined in the mixed condition, which mimicked the typical recognition-induced forgetting paradigm (Maxcey, 2016; Maxcey & Bostic, 2015; Maxcey, Bostic, & Maldonado, 2016; Maxcey & Woodman, 2014; Scotti, Janakiefski, & Maxcey, 2020).

✉ Keisuke Fukuda
keisuke.fukuda@utoronto.ca

1 Department of Psychology, University of Toronto Mississauga, 3359 Mississauga Rd North, Mississauga, ON L5L 1C6, Canada

2 University of Toronto, Toronto, Ontario, Canada

3 Fairleigh Dickinson University, Teaneck, NJ, USA

4 Carleton University, Ottawa, Ontario, Canada

5 Vanderbilt University, Nashville, TN, USA

Experiment 1

Method

Participants

In recent studies, the effect size of the recognition-induced forgetting was *Cohen's d* = 0.38 or larger (Maxcey, 2016; Maxcey, Glenn, & Stansberry, 2018; Maxcey & Woodman, 2014; Rugo, Tamler, Woodman, & Maxcey, 2017). Since we developed a new set of stimuli, we conservatively set our minimum effect size of interest to be 0.3. Given that we would be conducting a series of preplanned *t* tests as well as a within-subject ANOVA with two factors (i.e., recognition practice condition and item type), an a priori power calculation revealed that we would need 90 subjects to reliably observe the effect with the alpha level of 0.05 and statistical power of 0.8 (Faul, Erdfelder, Lang, & Buchner, 2007). This assured that we had sufficient sample size for both of our experiments.

Subjects were 91 first-year undergraduate students. Subjects participated in the 1-hour study after providing written informed consent according to procedures approved by the Research Ethics Board at the University of Toronto. All volunteers self-reported that they were neurologically normal, had normal or corrected-to-normal visual acuity, and were not color-blind.

Stimuli

We developed a new stimulus set of 630 total pictures of man-made objects for our experiments. The set consisted of six superordinate object categories (i.e., tools, electronics, instruments, kitchen items, office supplies, and toys, for example subject see Fig. 1) divided into 15 basic-level categories (e.g., for kitchen items, the 15 basic-level categories were table knives, can opener, bottle opener, fork, grater, chopping knives, nut cracker, basting brush, pizza cutter, rolling pin, spatula, table spoon, juicer, strainer, and wooden spoon) with seven different objects in each (e.g., seven different pizza cutters). The full stimulus set is available on Open Science Framework (https://osf.io/mje35). Each object was fit into a 10.4° × 10.4° rectangle and presented on a gray background (54.3 cd/m^2).

Procedure

Encoding phase The experiment began with the encoding phase (see Fig. 2), in which subjects were sequentially presented with objects and instructed to remember each object as precisely as possible. Each object was presented for 2 seconds, followed by a 500-ms blank display. Across the encoding phase, participants saw two objects (e.g., a picture of a red yo-yo is one object and a rainbow yo-yo is another object) from 15 basic-level object categories (e.g., one basic-level category is "yo-yo") from six superordinate-level categories (e.g., one superordinate-level category is "toy"), totaling 180 objects. Each object was presented twice in a random order, totaling 360 trials.

Recognition practice phase The encoding phase was followed by a 240-trial recognition practice phase. Objects were sequentially presented, and the subject's task was to determine whether they had seen the object during the encoding phase (i.e., the object is *old*) or not (i.e., the object is *new*) using six buttons on the keyboard. More precisely, subjects were instructed to press 1, 2, or 3 when they thought the object was *old* with 100%, 80%, and 60% certainty, respectively. If subjects thought the object was *new,* they were instructed to press 8, 9, or 0 to indicate 60%, 80%, or 100% certainty, respectively. We collected confidence ratings to determine whether any forgetting effects were isolated to certain portions along the confidence scale (e.g., weak confidence or strong confidence ratings) or were a general effect across the entire confidence scale.[1] Upon response, the object was replaced with a 500 ms central fixation dot, whose color provided 100% valid feedback for their response (i.e., green dot = correct, red dot = incorrect).

The recognition practice phase created three specific object types. An old object shown during the recognition practice phase is a *practiced* object. An old object not presented during the recognition practice phase but related to a practiced object (e.g., guitars were practiced, but not this particular guitar) is a *related* object. An object that belongs to a category of objects that were never practiced (e.g., none of the teddy bears were practiced) is a *baseline* object. In all recognition-induced forgetting studies to date, half the objects in the recognition practice phase were old objects (i.e., practiced and related objects), while half of them were new.

Here, the unique aspect of our design is to implement a within-subjects manipulation where one-third of the object categories replicated previous studies with an equal mix of new and old objects presented during the recognition practice phase (the *mixed* condition), but the remaining two-thirds of conditions were unique because one-third of the object categories had only old objects presented during the recognition practice phase (the *all-old* condition), and one-third of the object categories had only new objects presented during the recognition practice phase (the *all-new* condition). Next, we describe this distribution of recognition practice conditions (see Fig. 1).

Using random assignment, the six superordinate object categories from the encoding phase were equally divided into

[1] To preview the results, we found a general effect across the confidence scale (see ROC curves, Fig. 3) and were then able to collapse across confidence ratings for hit rate analyses.

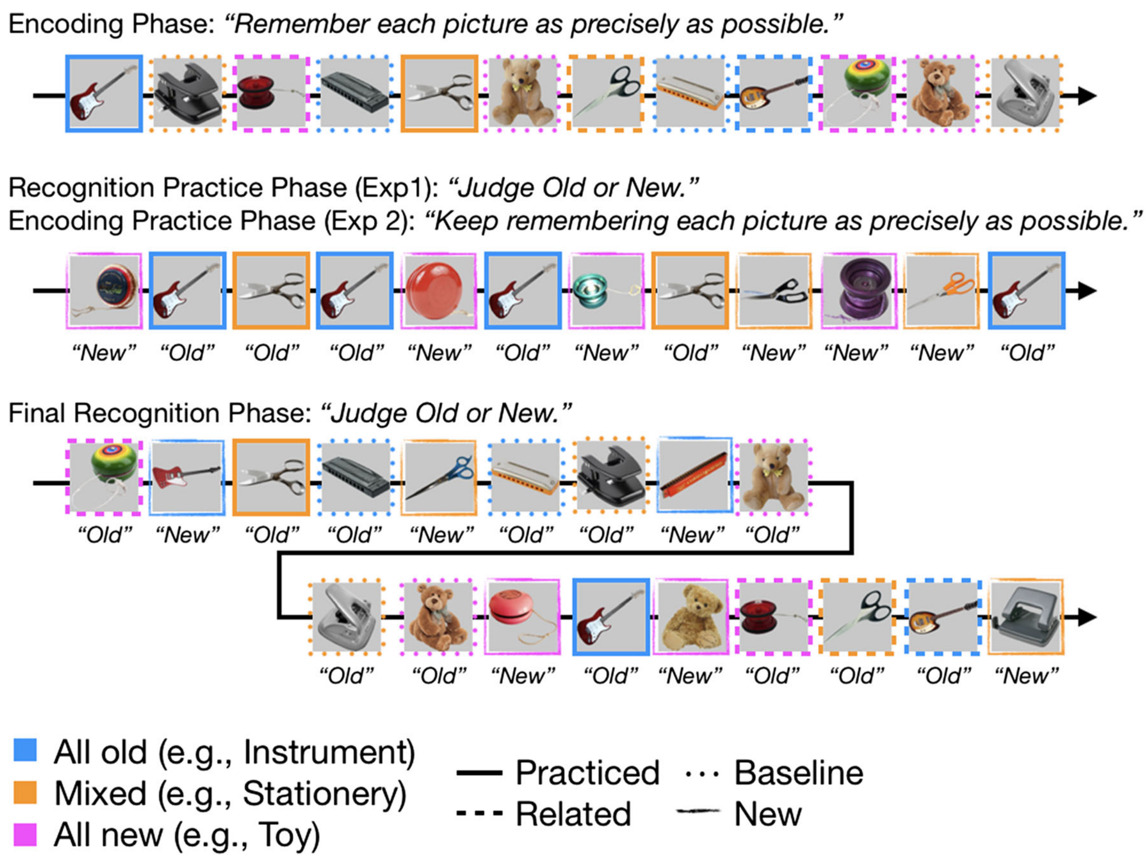

Fig. 1 Distribution of recognition practice conditions for a sample subject. For this particular subject, all 180 objects shown here were presented twice during the encoding phase. Then during the practice phase, the six superordinate categories labeled at the top (e.g., instruments, electronics) were equally divided into three conditions. For example, instruments and electronics were in the all-old condition, stationery and DIY tools were in the mixed condition, and toys and kitchen items were in the all-new condition. Ten objects from each superordinate category were used during the practice phase so these condition assignments determined the number of times these ten objects were practiced. Specifically, objects in the all-old condition were practiced 4 times, with no new objects on the remaining trials, objects in the mixed condition were practiced two times, with an equal number of new objects on the remaining trials, and objects in the all-new condition were practiced 0 times with four new objects on the remaining trials (the opposite of the all-old condition). Baseline objects (boxed in black) and related objects (boxed in pink) are excluded from the practice phase. Related objects are categorically neighboring objects to the practiced objects. Related objects are expected to be forgotten in recognition-induced forgetting following practice of a within-category neighbor (i.e., practiced objects). Forgetting of related objects is measured at test relative to baseline objects. New objects are not shown here because they were new to the subject and therefore could not have been shown to the subject during the encoding phase and all these objects were shown during the encoding phase.

three conditions—the all-old, mixed, and all-new conditions. In the all-old condition, the old objects were practiced four times. In the mixed condition, the old objects were practiced two times. Ten of the 15 basic-level object categories in each superordinate-level category were selected for use in this phase. The five remaining categories served as baseline objects,[2] as described below.

For the two superordinate categories in the all-old condition, half the objects (1 object × 10 basic-level categories × 2 superordinate categories = 20 total objects, see Fig. 1, boxed in blue) were presented four times across 80 total trials. The correct answer on all 80 trials in the all-old condition is “old.” These old objects are called all-old-practiced objects. The remaining half was not presented in this phase and is henceforth called “all-old-related objects”. Recall that 10 of the 15 basic-level object categories in each superordinate level category were selected for use in this phase, meaning that the two objects from five remaining basic-level object categories from each of the two categories in the all-old condition (2 objects × 5 basic-level object categories × 2 superordinate-level categories = 20 objects) were not involved in the second phase. These 20 objects are henceforth referred to as “all-old-baseline objects.”

[2] When we compared the performance for baseline items, there was a statistically significant effect such that the baseline memory performance (i.e., corrected recognition performance) was best for baseline objects in the all-old category, followed by mixed category and then all-new category. This was the case for both experiments. This suggests that the type of retrieval practice (i.e., all-old, mixed, or all-new) had a category-specific effect that propagated to baseline items. More precisely making more ‘old’ judgments helped memory performance for the baseline items from the same object category. This makes it inappropriate to collapse across all baseline items, and therefore justifies using category-specific baseline comparisons.

Fig. 2 General method of Experiments 1 and 2. The top, middle, and the bottom rows show the encoding phase, the recognition/encoding practice phase, and the final recognition phase, respectively. The "old" and "new" under each object indicates whether the object was presented during the encoding phase. The colored frames around each object indicate the different conditions. The line style indicates the object type. (Color figure online)

For the two superordinate categories in the mixed condition, half the old objects (1 object × 10 basic-level categories × 2 superordinate categories = 20 total objects; see Fig. 1, boxed in yellow) were presented two times across 40 total trials as mixed-practiced objects. The remaining half was not presented in this phase and is henceforth called "mixed-related objects." Forty new objects, corresponding to the same basic-level categories as the old objects, were presented across 40 trials, leading to a 50/50 old–new correct response distribution. The two objects from five remaining basic-level object categories from each of the two categories in the mixed condition were not involved in the second phase. These 20 objects are henceforth referred to as "mixed-baseline objects."

For the two superordinate categories in the all-new condition, there were no old objects presented. Rather, four new objects were presented from each of the 10 basic-level object categories in each of the two superordinate-level categories across 80 trials. Because there were no old items practiced in the second phase, there were no all-new practiced objects, and all the old objects from the two superordinate-level categories in the all-new condition were all-new-related objects. The two objects from five remaining basic-level object categories from each of the two categories in the all-new condition were not involved in the second phase. These 20 objects are henceforth referred to as "all-new baseline objects."

Recall that these recognition-practice conditions were within subjects such that each subject saw some objects in the all-old, mixed, and all-new conditions. In sum across the recognition practice phase, 40 old objects were presented across 120 trials, and 120 new objects were presented across 120 trials, totaling 160 objects and 240 trials with a 50/50 old–new correct response distribution.

Final recognition phase The experiment ended with the final recognition test. In this phase, participants were presented with one object at a time and completed an old–new recognition judgment task using the same buttons as the recognition practice phase. Feedback was not provided.

From the all-old condition, 20 practiced objects (2 superordinate categories × 10 basic-level categories × 1 object), 20 related objects (2 superordinate categories × 10 basic-level categories × 1 object), and 20 baseline objects (2 superordinate categories × 5 basic-level categories × 2 objects) were presented as old objects. From the mixed condition, 20 practiced objects (2 superordinate categories × 10 basic-level categories × 1 object), 20 related objects (2 superordinate categories × 10 basic-level categories × 1 object), and 20 baseline objects (2 superordinate categories × 5 basic-level categories × 2 objects) were presented as old objects. For the all-new condition, 40 related objects (2 superordinate categories × 10 basic-level categories × 2 objects) and 20 baseline objects (2 superordinate categories × 5 basic-level categories × 2 objects) were presented as old objects. Finally, this phase included 90 (6 superordinate categories × 15 basic-level categories × 1 object) new objects that were never presented previously in the experiment. Even though the difference in the total number of old and new pictures might introduce a response bias, our dependent measure of memory performance (i.e., corrected recognition rate = hit rate − false-alarm rate) was computed to cancel such response bias.[3]

[3] Further to anticipate our results, we found statistically indistinguishable forgetting in all three conditions, suggesting that the results are not due to subjects shifting response criterion across conditions.

Reporting Bayes factors for examining null effects Because some of our key hypotheses predicted null results, we additionally report Bayes factors (BF). The reported BF for each analysis is calculated in favor of our hypothesis of interest. BF_{null} indicates a Bayes factor in favor of the null hypothesis.

Results

Recognition practice phase

The hit rate for old objects (i.e., the proportion of old responses across confidence levels) was .92 (SE = 0.01) and .87 (SE = 0.01) for all-old and mixed conditions, respectively. The false-alarm rate for new objects (i.e., the proportion of old responses across confidence levels) was .17 (SE = 0.01) and .19 (SE = 0.01) for mixed and all-new conditions, respectively. These results confirmed that participants successfully encoded objects presented during the encoding phase and were engaged in the recognition practice task.

Final recognition phase

To remove any response bias that participants might have exhibited, recognition performance was measured by the corrected recognition rate (i.e., hit rate − false-alarm rate; Feenan & Snodgrass, 1990) and is reported here with the mean followed by standard error (see Fig. 3; see Table 1 for complete recognition data set). In Experiment 1, a series of preplanned t tests revealed that we successfully replicated recognition-induced forgetting, in which memory for related objects is reliably lower than memory for baseline objects across all conditions. Replicating previous studies on recognition-induced forgetting, in the mixed condition, memory for practiced objects (66, 0.02) was significantly better than memory for baseline objects (.41, 0.02), $t(90)$ = 14.0, p < .001, $BF = 1.3\times10^{21}$, and memory for related objects (0.37, 0.02) was significantly worse than memory for baseline objects, $t(90)$ = 2.5, p < .05, BF = 2.0. In the all-old condition, memory for practiced objects (.78, 0.02) was significantly better than memory for baseline objects (0.45, 0.02), $t(90)$ = 17.7, p < .001, $BF = 7.1\times10^{27}$, and memory for related objects (0.39, 0.02) was significantly worse than memory for baseline objects, $t(90)$ = 3.7, p < .001, $BF = 5.0\times10^{1}$. Recognition alone led to forgetting. In the all-new condition, memory for related objects (0.37, 0.02) was significantly worse than memory for baseline objects (0.41, 0.02), $t(90)$ = 14.0, $t(90)$ = 2.6, p < .05, BF = 2.7. Correct rejections alone led to forgetting. Reliable recognition-induced forgetting in the all-old and all-new conditions is particularly notable because valid feedback after every trial in the practice phase could have made the

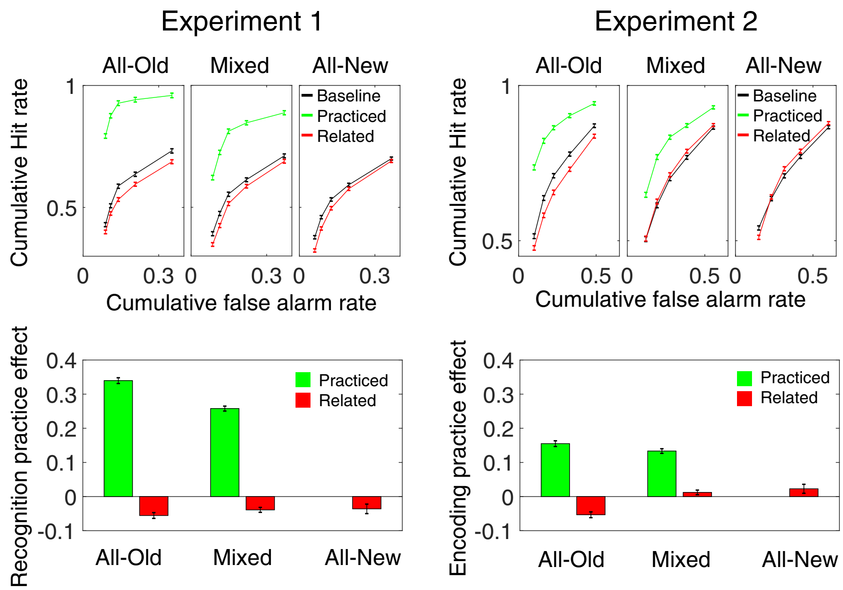

Fig. 3 Results of Experiments 1 and 2. The top panel shows the receiver operating characteristics (ROC) curves (Yonelinas, 1994; Yonelinas & Parks, 2007), demonstrating the consistency of forgetting across a range of confidence ratings. The error bars represent the within-subject standard errors of the mean. ROC curves here are used to ensure that the forgetting effect is not driven by isolated portions of the confidence scale (e.g., weak confidence or strong confidence ratings). As you can see, forgetting was consistent across confidence ratings. These ROC curves provided evidence that we were looking at a general effect across the entire confidence scale, so we collapsed across confidence ratings in the bottom figure. The bottom figure shows the difference in the corrected recognition performance between object types (i.e., practiced and related) and the baseline condition

manipulation obvious to the subjects and thus made them implement corresponding response strategies (e.g., a subject might realize that they should always respond "new" to items in the all-new category and "old" to items in the all-old category). However, the fact that we observed equivalent degrees of forgetting in both conditions indicates that the forgetting was not the result of such response strategies.

To compare the magnitude of recognition-induced forgetting across the three conditions, recognition memory was subjected to 2 (object types: related, baseline objects) × 3 (conditions: all-old, mixed, all-new) repeated-measures ANOVA. The result revealed an expected main effect of object type, $F(1, 90) = 20.4$, $p < .01$, BF = $8.6{\times}10^1$, because memory for baseline objects was better than memory for related objects across all three conditions. However, there was no main effect of condition, $F(2, 180) = 2.3$, $p = .10$, $BF_{null} = 1.5$, or interaction between condition and object type, $F(2, 180) = 0.6$, $p = .58.$, $BF_{null} = 2.0{\times}10^1$, demonstrating that the magnitude of forgetting was the same across all three conditions. Recognition and correct rejection tasks each caused recognition-induced forgetting that was statistically indistinguishable from the forgetting typically induced by combining both recognition and correct rejections. These results demonstrate that correct rejection and recognition are basic building blocks of forgetting, each singularly sufficient to cause recognition-induced forgetting.

Experiment 2

Evidence of recognition-induced forgetting in the all-new condition in Experiment 1 is particularly striking because this condition removed all old objects from the practice phase, simply requiring the subject to identify all objects as new rather than recognizing any of the objects as old. It is generally believed that the recognition of the old objects during the second phase is precisely what induces forgetting. One may argue that forgetting in the all-new condition is due to the interference of more overall objects in the second phase than the other conditions. This alternative explanation is possible because the overall number of new objects in the second phase of the all-new condition is larger (80/80 trials are new objects) than the mixed (40/80 objects are new) and all-old conditions (0/80 are new objects). In Experiment 2, we asked whether recognition-induced forgetting in the all-new condition resulted from interference caused by perceiving and encoding new objects in the second phase rather than making correct rejections. To this end, we simply changed to task of the second phase. We replaced the recognition practice phase with an encoding practice phase, which simply meant a change in instructions to the subjects. Subjects were instructed to encode the objects rather than make old-new recognition judgments in the second phase. Critically, the number of new items in each condition was the same as in Experiment 1 (i.e., 80 new objects in the all-new condition, 40 new objects in the mixed

Table 1. Recognition performance for Experiment 1 and 2

	Experiment 1						Experiment 2					
	100% Old	80% Old	60% Old	60% New	80% New	100% New	100% Old	80% Old	60% Old	60% New	80% New	100% New
All-old Practiced	0.82 (0.02)	0.06 (0.01)	0.04 (0.01)	0.02 (0.00)	0.02 (0.00)	0.04 (0.00)	–	–	–	–	–	–
Mixed Practiced	0.75 (0.02)	0.06 (0.01)	0.06 (0.01)	0.03 (0.00)	0.04 (0.01)	0.06 (0.01)	–	–	–	–	–	–
Mixed New	0.11 (0.01)	0.02 (0.00)	0.03 (0.00)	0.07 (0.01)	0.12 (0.02)	0.65 (0.03)	–	–	–	–	–	–
All-new New	0.12 (0.01)	0.03 (0.01)	0.04 (0.01)	0.08 (0.01)	0.14 (0.01)	0.59 (0.01)	–	–	–	–	–	–
All-old Practiced	0.79 (0.02)	0.08 (0.01)	0.05 (0.01)	0.01 (0.00)	0.02 (0.00)	0.04 (0.01)	0.74 (0.02)	0.09 (0.01)	0.04 (0.01)	0.04 (0.01)	0.04 (0.01)	0.06 (0.01)
All-old Related	0.40 (0.02)	0.08 (0.01)	0.06 (0.01)	0.06 (0.01)	0.09 (0.01)	0.31 (0.02)	0.48 (0.02)	0.11 (0.01)	0.07 (0.01)	0.07 (0.01)	0.11 (0.01)	0.16 (0.02)
All-old Baseline	0.43 (0.03)	0.07 (0.01)	0.08 (0.01)	0.05 (0.01)	0.10 (0.01)	0.27 (0.02)	0.52 (0.02)	0.12 (0.01)	0.07 (0.01)	0.07 (0.01)	0.09 (0.01)	0.13 (0.01)
All-old New	0.09 (0.01)	0.02 (0.00)	0.03 (0.01)	0.07 (0.01)	0.15 (0.02)	0.65 (0.02)	0.10 (0.01)	0.06 (0.01)	0.06 (0.01)	0.10 (0.01)	0.16 (0.01)	0.51 (0.03)
Mixed Practiced	0.62 (0.03)	0.10 (0.01)	0.09 (0.01)	0.03 (0.01)	0.04 (0.01)	0.11 (0.01)	0.64 (0.02)	0.12 (0.01)	0.06 (0.01)	0.04 (0.01)	0.06 (0.01)	0.07 (0.01)
Mixed Related	0.35 (0.02)	0.08 (0.01)	0.09 (0.01)	0.07 (0.01)	0.10 (0.01)	0.31 (0.02)	0.51 (0.02)	0.12 (0.01)	0.09 (0.01)	0.08 (0.01)	0.08 (0.01)	0.13 (0.01)
Mixed Baseline	0.39 (0.02)	0.08 (0.01)	0.08 (0.01)	0.06 (0.01)	0.10 (0.01)	0.29 (0.02)	0.51 (0.02)	0.11 (0.01)	0.09 (0.01)	0.07 (0.01)	0.10 (0.01)	0.14 (0.01)
Mixed New	0.09 (0.01)	0.03 (0.00)	0.03 (0.00)	0.07 (0.01)	0.15 (0.02)	0.63 (0.02)	0.12 (0.01)	0.07 (0.01)	0.08 (0.01)	0.11 (0.01)	0.17 (0.01)	0.44 (0.02)
All-new Related	0.32 (0.02)	0.09 (0.01)	0.08 (0.01)	0.08 (0.01)	0.11 (0.01)	0.31 (0.02)	0.51 (0.02)	0.13 (0.01)	0.09 (0.01)	0.06 (0.01)	0.09 (0.01)	0.12 (0.01)
All-new Baseline	0.38 (0.02)	0.08 (0.01)	0.07 (0.01)	0.06 (0.01)	0.11 (0.01)	0.3 (0.02)	0.54 (0.02)	0.09 (0.01)	0.07 (0.01)	0.06 (0.01)	0.09 (0.01)	0.13 (0.02)
All-new New	0.06 (0.01)	0.03 (0.00)	0.04 (0.01)	0.07 (0.01)	0.17 (0.02)	0.63 (0.03)	0.15 (0.01)	0.08 (0.01)	0.08 (0.01)	0.10 (0.01)	0.18 (0.01)	0.40 (0.02)

Table 1. Recognition performance for Experiment 1 and 2
The white background cells represent the response distribution across confidence levels in the recognition practice phase of Experiment 1. The blue, orange, and pink background cells represent the response distributions in the final recognition phase for all-old, mixed, and all-new conditions of Experiment 1 and 2. The numbers in parentheses represent the standard errors of the mean.

The white background cells represent the response distribution across confidence levels in the recognition practice phase of Experiment 1. The blue, orange, and pink background cells represent the response distributions in the final recognition phase for all-old, mixed, and all-new conditions of Experiments 1 and 2. The numbers in parentheses represent the standard errors of the mean. (Color table online)

condition, and zero new objects in the all-old condition). If interference from new objects in the second phase, rather than completing an old–new recognition judgment task, led to forgetting in the all-new condition in Experiment 1, then recognition-induced forgetting will still occur in Experiment 2. If forgetting in the all-new condition of Experiment 1 is due to the task (i.e., all correct rejections to new objects) in the second phase, then forgetting will not occur in Experiment 2.

Method

The method of Experiment 2 was identical to that of Experiment 1, with the following exceptions.

Participants

Participants were 90 new first-year undergraduate students.

Procedure

Encoding practice phase During the second phase, participants were presented with the same number of old and new objects (160 total objects), one at a time, for 2 seconds, as in the recognition practice phase in Experiment 1. However, unlike Experiment 1, participants were instructed to continue to remember each object as precisely as possible. As a result, just like the encoding phase, participants provided no response, and no feedback was given. The objects were selected and grouped in the same manner as the recognition practice phase of Experiment 1.

Results

In the all-old condition, memory for practiced objects (0.64, 0.02) was significantly better than memory for baseline objects (0.48, 0.02), $t(89) = 12.1$, $p < .001$, $BF = 3.2\times10^{17}$, and memory for related objects (0.43, 0.02) was significantly worse than memory for baseline objects, $t(89) = 3.7$, $p < .001$, $BF = 5.2\times10^{1}$, demonstrating recognition-induced forgetting. These results replicate our existing evidence that restudy of pictures leads to forgetting (Maxcey, Janakiefski, et al., 2019b) and may be due to subjects engaging in a recognition task of the old objects despite instructions to restudy due to the visually distinct nature of the pictures. Regardless, the critical condition in

Experiment 2 is whether recognition-induced forgetting persists in the all-new condition. In the mixed condition, memory for practiced objects (0.56, 0.02) was significantly better than memory for baseline objects (0.43, 0.02), $t(89) = 10.0$, $p < .001$, BF = 2.7×10^{13}, but unlike Experiment 1, memory for related objects (0.44, 0.02) was not reliably worse than memory for baseline objects, $t(89) = 0.9$, $p = .35$, $BF_{null} = 5.6$. Further, unlike Experiment 1, in the all-new condition, memory for related objects (0.42, 0.02) was not significantly worse than memory for baseline objects (0.39, 0.02), $t(90) = 10.0$, $t(89) = -1.7$, $p = 0.09$., $BF_{null} = 2.0$. The absence of recognition-induced forgetting in the critical all-new condition when recognition practice from Experiment 1 was replaced with encoding practice in Experiment 2 rules out the alternative explanation that interference from new items caused forgetting in Experiment 1. This is because if the additional new items were causing forgetting, rather than the recognition task, recognition-induced forgetting would have persisted. This confirms that it was conducting correct rejections in Experiment 1 that led to forgetting.

To compare the magnitude of recognition-induced forgetting across three recognition practice conditions, recognition memory was subjected to a 2 (object type: baseline, related) × 3 (condition: all-old, mixed, all-new) repeated-measures ANOVA. The result revealed a main effect of condition, $F(2, 178) = 3.8$, $p < .05$, BF favoring the effect of encoding practice = 1.2×10^{1}. This was exclusively driven by the difference in baseline memory performances between all-old and mixed, $t(89) = 2.8$, $p < .01$, BF favoring all-old > mixed = 4.9, and all-old and all-new, $t(89) = 4.7$, $p < .001$, BF favoring all-old > all-new = 2.0×10^{3}, but not mixed and all-new, $t(89) = 1.3$, $p = .19$, $BF_{null} = 3.6$. There was no difference in memory across related items (all-old and mixed), $t(89) = -0.4$, $p = .73$, $BF_{null} = 8.1$; all-old and all-new, $t(89) = 0.7$, $p = .48$, $BF_{null} = 6.7$; mixed and all-new, $t(89) = 1.0$, $p = .34$, $BF_{null} = 5.5$. Importantly, there was an expected interaction between condition and object type, $F(2, 178) = 10.1$, $p < .001$, BF favoring the interaction = 2.2, without the main effect of item types, $F(1, 89) = 0.5$, $p = .47$, $BF_{null} = 9.2$. Taken together, the results of Experiment 2 revealed that interference caused by the encoding of new related items did not cause the recognition-induced forgetting observed in Experiment 1.

Discussion

Demonstrations of recognition-induced forgetting involve the recognition of objects stored in memory and the correct rejection of lures. Until now, it has been unclear whether both tasks are necessary to cause recognition-induced forgetting or if one or the other is sufficient to induce forgetting. We found that recognition and correct rejections each produced forgetting. Importantly, the degree of forgetting induced by recognition and correct rejections was statistically indistinguishable from the forgetting caused by the two combined. In Experiment 2, we confirmed that this novel type of recognition-induced forgetting was not the result of the additional encoding of new memories, highlighting the causal role that correct rejections play in the recognition-induced forgetting. These results also rule out list length explanations of recognition-induced forgetting (see also Maxcey, 2016) because the effect was consistent across shorter lists (e.g., all-old, 40 old objects repeated twice) and longer lists (e.g., all-new, 80 new objects with no repeats).

Taken together, our results inform theoretical accounts of induced forgetting (Anderson, 2003; Jonker, Seli, & MacLeod, 2013; Lewis-Peacock & Norman, 2014; Murayama, Miyatsu, Buchli, & Storm, 2014; Raaijmakers & Jakab, 2013) by showing that forgetting can be induced by either the physical presentation of old memories or the correct rejection of new memories, underscoring the ubiquity of this robust forgetting effect (Maxcey, Dezso, Megla, & Schneider, 2019a). The collection of real-world scenarios involving recognition or correct rejection tasks that may induce forgetting is ample, such as radiologists and dermatologists determining whether an unusual growth is cancer, students answering a true-or-false statement, and eyewitnesses to a crime determining whether a criminal is present in a lineup.

Author contributions K.F., S.P., and A.M. designed the experiments. S.P. and E.C. conducted the experiments. K.F. analyzed the data. A.M. and K.F. wrote the manuscript.

Compliance with ethical standards

Conflict of interests The authors declare no competing financial interests.

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