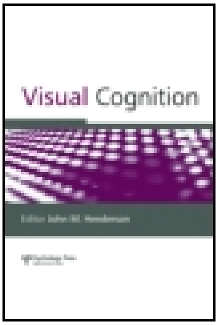

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Forgetting induced by recognition of visual images

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Forgetting induced by recognition of visual images

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Retrieval-induced forgetting is a phenomenon in which groups of stimuli are initially learned, but then a subset of those stimuli are subsequently remembered via retrieval practice, causing the forgetting of other initially learned items. This phenomenon has almost exclusively been studied using linguistic stimuli. The goal of the present study was to determine whether our memory for simultaneously learned visual stimuli was subject to a similar type of memory impairment. Participants were shown real-world objects, then they practised recognizing a subset of these remembered objects, and finally their memory was tested for all learned objects. We found that practising recognition of a subset of items resulted in forgetting of other objects in the group. However, impaired recognition did not spread to new objects belonging to the same category. Our findings have important implications for how our memories operate in real-world tasks, where remembering one object or aspect of a visual scene can cause us to forget other information encoded at the same time.

Keywords: Visual long-term memory; Recognition; Forgetting.

Many real-world memory tasks require us to store an array of objects in long-term memory so that we can later remember some or all of this information.

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For example, the often-discussed task of an eyewitness to a crime requires the observer to remember the details of the person perpetrating that crime, the method they used (e.g., the weapon, the accomplice, the get-away car, etc.), and the other people present at the time that could also be witnesses. It is possible that when we remember certain details of these critical visual events, we actually harm our memories of the details that we are not pulling out of long-term memory. The long-term memory literature would suggest that this is likely to be true based on studies of retrieval-induced forgetting, in which groups of stimuli from the same category are initially learned and then the act of retrieving some members of the group causes forgetting of the other nonretrieved members of the group (Anderson, Bjork, & Bjork, 1994). Although such a memory impairment may heavily impact real-world visual memory, it has been studied almost exclusively using verbal stimuli (i.e., words, but see later for our discussion of exceptions to this rule). In addition, there are reasons to believe that long-term memory for visual information may operate according to different principles than memory for verbal information. The goal of the present study was to determine whether memory for visual information is impaired following recognition of related items, similar to the way in which verbal information is impaired by retrieving related items. If it is, then this has important implications for real-world memory tasks, like the one performed by an eyewitness.

In the present study, we examined whether a memory impairment, similar to retrieval-induced forgetting, can be observed as a consequence of recognizing specific pieces of visual information. Retrieval-induced forgetting is the well-known phenomenon in which responding to one piece of verbal information can actually hurt our memory representation of another piece of verbal information learned at the same time (Anderson et al., 1994). When participants are presented with CATEGORY:exemplar pairs such as FRUIT:banana, FRUIT:apple, and VEGETABLE:pea during a primary study phase, and then practise retrieving FRUIT:banana from memory during a middle practice phase, they show better memory for banana, which they practised, relative to pea and apple in a final test phase. Interestingly, participants also show better performance for pea than for apple, despite having not practised either of these items. This is an intriguing finding because participants consistently have poorer performance for nonpractised exemplars (e.g., apple) from practised categories (e.g., fruit) relative to nonpractised exemplars (e.g., pea) from nonpractised categories (e.g., vegetable).

Despite the focus on visual processing in studies of perception, rarely have studies examined memory impairments like retrieval-induced forgetting with visual information. Here we discuss two exceptions (see also Fan & Turk-Browne, 2013; Johansson & Hanslmayr, 2012). First, Shaw, Bjork, and Handal (1995) examined retrieval-induced forgetting in an eyewitness testimony paradigm. Participants were shown slides depicting the aftermath of a theft in a college student's apartment. The apartment images included two target categories, college sweatshirts and college textbooks, with eight items in each category. In an interrogation phase designed to mimic a retrieval-practice phase, participants were asked to recall particular details of the crime scene. This verbal recall was designed to target half of the items in one of the categories (e.g., four sweatshirts) and consisted of questions about the crime scene. The results showed typical retrieval-induced forgetting in this paradigm using visual stimuli and a verbal retrieval-practice phase. Second, Ciranni and Shimamura (1999) noted that retrieval-induced forgetting paradigms had employed only well-learned stimuli and hypothesized that the forgetting occurs because the categories that items are drawn from were formed well before the participants entered the laboratory. The researchers presented participants with 12 shapes (four circles, four triangles, and four crosses) that were assigned a particular colour and a specific spatial location. After participants learned the novel stimulus–location pairings, participants completed a retrieval-practice phase, consisting of recalling the colours of half of the circles and crosses using shape and location as the retrieval cues. At test, participants showed the typical retrieval-induced forgetting effect (i.e., worse memory for nonpractised coloured shapes initially studied at the same time as practised items), suggesting this phenomenon can be demonstrated when information has just been learned.

Neither of the two studies reviewed above (Ciranni & Shimamura, 1999; Shaw et al., 1995) specifically examine how remembering certain real-world visual objects impairs our memory for other such objects. Specifically, the Ciranni and Shimamura (1999) study did not use real-world stimuli with ecologically valid semantic relationships. In addition, the Shaw et al. (1995) study utilized a verbal recall procedure, rather than a visual recall procedure. This is understandable, given that it is not readily apparent how to conduct a well-controlled laboratory experiment in which participants recall visual object representations. For example, the closest visual task that would utilize *retrieval*, mimicking word-stem completion, would be instructing participants to draw a picture given several initial line segments. However, such a task does not lend itself to quantitative measures of performance.

Our solution here was to study *recognition*-induced forgetting using stimuli that were visually presented, real-world objects with ecologically valid categorical relationships. This allowed us to ask whether recognizing information using visual long-term memory affects memory for both the recognized item as well as related items. It is an open question whether this novel extension of the retrieval-induced forgetting phenomenon would be observed at all given the existing evidence for astonishingly accurate recognition memory for visual objects and pictures (Brady, Konkle, Alvarez, & Oliva, 2008; Standing, 1973). These findings suggest that visual representations may be immune to classic long-term memory impairments, such as retrieval-induced forgetting, found with verbal stimuli. It may be the case that recognizing visual information, unlike retrieving verbal representations from long-term memory, does not alter visual long-term memory representations.

In the present study, our primary goal was to test the hypothesis that representations in visual long-term memory are sufficiently veridical to be immune to a recognition-based impairment, unlike retrieval-induced forgetting of verbal materials. This hypothesis was motivated, first, by the evidence that long-term memory is superior for visual materials compared to verbal materials (Nelson & Reed, 1976; Nelson, Reed, & Walling, 1976; Pavio, 1969, 1971), and, second, by evidence that retrieval-based memory impairments do not consistently translate into similar recognition-based impairments (Anderson & Bjork, 1994; Butler, Williams, Zacks, & Maki, 2001; Hicks & Starns, 2004; Koustaal, Schacter, Johnson, & Galluccio, 1999; MacLeod, 1999; Tversky, 1973).

As shown in Figure 1, our paradigm in the present study followed classic retrieval-induced forgetting paradigms as closely as possible while substituting visual stimuli for verbal stimuli and using recognition practice and test phases in place of retrieval practice and test phases. During the initial *study phase*, we showed participants a series of pictures of real-world objects that belonged to a variety of semantic categories (i.e., cars, muffins, baskets, etc.). After this initial study phase, we required participants to recognize half of the objects from half of the studied categories by identifying which of two objects was the familiar object rather than a semantically related lure during the recognition-practice phase. Finally, during the test phase, we used a forced choice, old-versus-new judgement to test the participants' memory for items shown in the study phase (some of which were practised), as well as correct rejection rates to novel objects not previously seen. If visual long-term memory operates according to principles that govern verbal long-term memory, then we should observe recognition-induced forgetting here. This would be supported by our observation of superior performance for practised items (e.g., the bright red car in Figure 1) and poorest performance for items that were not practised, but belonged to practised categories (e.g., the chocolate chip muffin in Figure 1) relative to items in nonpractised categories (e.g., the basket in Figure 1). Alternatively, if representations in visual long-term memory are immune to recognition-induced forgetting due to this form of long-term memory being more accurate than verbal long-term memory, then we should see that participants' memory for all of the items they observed during the study and recognition-practice phases should be similarly accurate.

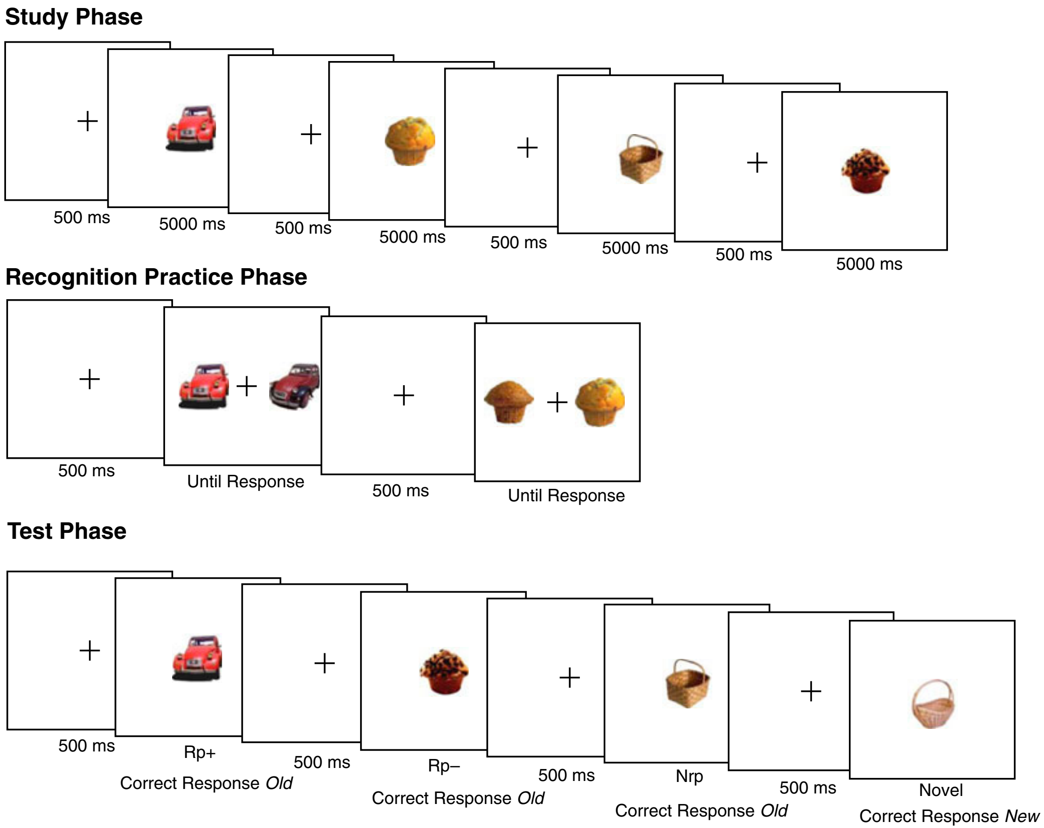

Figure 1. Example of the stimuli and procedure. The study phase consisted of 78 items presented sequentially for 5 s interleaved by a 500 ms fixation cross. Participants were instructed to study the visual details of each image for a later memory test. During the recognition practice phase, participants were shown half the items from half the categories from the study phase. These items were paired with another exemplar from the same category. Participants responded by button press to indicate which item (the item on the left or right) was the item they studied in the previous phase. To view this figure in colour, please see the online issue of the Journal.

EXPERIMENT 1

Our development of a visual recognition-induced forgetting paradigm in Experiment 1 allowed us to test correct rejections for new, semantically related objects, a class of representations that was not possible to probe in paradigms examining forgetting with verbal retrieval tasks. That is, we presented items in the test phase at the end of the experiment that required a recognition judgement (i.e., old versus new). The new items (which we call *test lures*) belonged to practised categories (e.g., car) but were never seen in the experiment. It has not been possible to test correct rejection rates for test lures from practised categories previously because paradigms have typically probed memory via a retrieval task (e.g., word-stem completion), which presumably could not have been completed with a novel word (for an exception using recognition and verbal stimuli, see Hicks & Starns, 2004). Our ability to test correct rejections to test lures enables us to examine whether a memory impairment of nonpractised items in a category like car actually spreads to all cars or simply to cars presented in the experiment. If participants perform poorly on test lures—in other words, they fail to correctly report a test lure as new rather than old—this would be interpreted in memory activation models as spreading activation within that category. Thus, the paradigm we developed in the present study, capitalizing on visual stimuli and a recognition task, allowed us to examine aspects of memory impairment that have not been possible to assess within the typical retrieval-induced forgetting paradigm.

Assuming that recognition-induced forgetting is observed for object representations stored in visual long-term memory, our secondary goal was to test the hypothesis that the memory impairment for nonpractised exemplars from practised categories affects only exemplars that were shown during study. There are three possible patterns of correct rejections to test lures in this paradigm. First, participants could show a decrease in correct rejections to test lures from practised categories relative test lures from nonpractised categories. This decrease in correct rejections would indicate that participants are reporting unfamiliar items as familiar when they belong to practised categories. From a spreading activation perspective, this would suggest that recognition practice of items in a category spreads activation to other exemplars. Second, participants could show an increase in correct rejections for test lures from practised categories relative to test lures from nonpractised categories. Such an increase in correct rejections would be indicative of increased inhibition or a lower level of activation for those nonpractised exemplars. Third, correct rejections could not reliably differ between test lures from practised and nonpractised categories. This third alternative would suggest that the costs and benefits of practice are object specific and that neither the costs nor the benefits spread throughout the category.

The third alternative we just discussed would also alleviate at least two potential alternative explanations for the findings that do not need to assume the existence of recognition-induced forgetting. The first potential alternative explanation that we consider here is based on the idea that responses towards practised categories are due to having more competitors in memory from that category. Specifically, our procedure for recognition practice in this paradigm involved exposing participants to six more exemplars from each practised category that served as lures during recognition practice. We call these *practice lures*. One might argue that this creates more competitors in memory and subsequently causes a detrimental effect in performance for objects belonging to practised categories. However, both increased performance for practised items relative to nonpractised items, as well as similar correct rejection rates for test lures from practised and nonpractised categories, would falsify such an account. Another possible argument that would be ruled out by support for this third alternative is that the task of responding to the familiar item in the two-alternative-forced-choice recognition-practice phase causes a criterion shift in responding to old versus new items. This would be ruled out by evidence that there is no reliable difference between correct rejections for lures belonging to practised and nonpractised categories.

Method

Participants. Twenty participants from Manchester University, aged 18–30 years old, who passed the Ishira colour blindness test, and reported normal or corrected-to-normal vision, were compensated $10 for participation. Informed consent was obtained prior to procedures approved by the Manchester University Institutional Review Board.

Stimuli. Stimuli were presented on a flat-screen 16-inch CRT monitor using E-prime 2.0 software (Schneider, Eschmann, & Zuccolotto, 2012). A viewing distance of 80 cm was controlled by a forehead rest. Stimuli were drawn from a set of 180 real-world objects (Brady et al., 2008, available at http://cvcl.mit.edu/MM/objectCategories.html, supplemented with public domain images downloaded from Google Images http://images.google.com), subdivided into 14 categories with 15 exemplars in 12 of the categories and 6 exemplars in the remaining 2 categories. Stimuli were viewed on a white background, with each subtending 9.44° × 7.13° degrees of visual angle.

Procedure. An example of the stimuli and procedure is shown in Figure 1. Each session began with a study phase. During the study phase, participants were shown one object at a time on the screen for 5 s, interleaved by a 500 ms centre fixation cross, until 78 objects had been randomly presented. Objects were randomly selected and belonged to 12 categories (e.g., car, muffin) with six exemplars in each category.[1] Participants were instructed to study the visual details of these items for a later memory test. They were told that the later test would require memory for an item as detailed as “red bike with banana seat”; therefore, simply remembering the category “bike” would not help at test. To minimize the influence of primacy and recency effects (Murdock, 1962) three filler items from two additional categories were included in the beginning and end of the study phase but were not included in the analysis. Thus, six of the 78 objects were excluded from analysis due to their status as filler items.

The purpose of the recognition-practice phase was to practice participants on recognizing half of the items from half of the categories they were shown in the study phase. During study, participants were shown six items from 12 categories. Then, in this recognition-practice phase participants practised recognizing three randomly selected items from six randomly selected categories, or 18 total objects. Each practised item was shown twice during this recognition-practice phase and was paired with a new practice lure from the same semantic category each time it was presented. The practice phase consisted of 36 randomly presented trials. The specific object categories that were practised were counterbalanced across subjects, such that practice lures for one participant may have been studied objects for another participant. Participants were shown two objects at a time on the screen, one to the left and one to the right of fixation. One of the objects was an object they were shown during the study phase; the other object was a practice lure from the same category. Participants were instructed to determine which of the items they had seen before and respond with a two-alternative-forced-choice button press. They pressed the left key on the response box with their right index finger if the item from the study phase was on the left and the right key on the response box with their middle finger if the item from the study phase was on the right. The trials were response terminated and followed by a 500 ms centre fixation cross before the next trial. Before and after recognition practice, participants completed a 5-minute distractor task, during which they made a list of countries and ranked the attractiveness of celebrities. This distractor task was adapted from Macrae and Roseveare (2002).

[1] The retrieval-induced forgetting effect relies on the existing categorical associations between items (e.g., chocolate-chip muffin and bran muffin) to cause interference between items from the same category. We presumed that because pictorial meaning can be conveyed without naming and the pictorial superiority effect is retained without naming (Nelson & Reed, 1976), participants would categorize objects without any verbal encouragement and exhibit retrieval-induced forgetting for objects belonging to the same category. In other words, completing recognition practice on one car will only impair memory for another nonpractised car as long as both are encoded as members of the same specific category “car”. This would also be consistent with recent evidence of within-category interference for visual long-term memory (Konkle, Brady, Alvarez, & Oliva, 2010).

During the test phase, participants were shown one object at a time and asked to report whether they had ever seen the exact image previously in the experiment, at any point, and respond with a button press. They pressed the left key on the response box with their right index finger if the answer was "yes" and the right key on the response box with their right middle finger if the answer was "no", from this point forward known as the old-versus-new judgement. These images fell into four categories. In three of the categories the items were old and participants responded "yes" if correct: (1) Rp+ items were shown both during the study phase and practised in the recognition-practice phase; (2) Rp− items were shown during the study phase and then were *not* practised in the recognition-practice phase but their category was practised (e.g., cars were practised but not that specific car); (3) Nrp items were shown during the study phase and then were *not* practised in the recognition-practice phase and their category was *not* practised (e.g., a basket and baskets were not practised). The fourth category consisted of new items and warranted a "no" response: (4) Test lures were items that were never seen before in the experiment. Test lures were drawn from all of the same 12 categories as the objects during the study phase, such that half of the test lures belonged to the six practised categories and six belonged to categories that were not practised. Note that we follow retrieval-induced forgetting nomenclature of defining these response categories as Rp+, Rp−, and Nrp, but here the "r" strands for recognition, not retrieval.

At test, we presented participants with 36 test lures and 36 old items so that "no" and "yes" responses were equally probable. The test trial distribution consisted of (1) two Rp+ and 2 Rp− items from each of the six practised categories, (2) two Nrp items from each of the six nonpractised categories, and (3) three test lures from each of the 12 categories. Therefore, half of the items in the memory test were previously shown (36 total Rp+, Rp−, and Nrp items) and half of the items were not previously shown (36 total test lures). All objects were randomly presented during test, regardless of their membership in any of these types of trials. Practice lures that were selected against during the recognition-practice phase were never included in the test phase. Test lures consisted of additional novel exemplars from each category that had never been presented in the experiment. However, instructions given to the participants before they began the test phase clearly stated that if they had *ever* seen an object before, at any point in the experiment, they should answer "yes" they had seen the item before.

Data analysis. The primary dependent variable for our recognition data was percentage correct (i.e., hits for Rp+, Rp−, and Nrp items, and correct rejections for test lures). We found the same pattern of results when we computed d', so we only report percentage correct for efficiency of presentation. We used within-subjects analysis of variance (ANOVA) and an alpha level of $p = .05$. Follow-up analyses consisted of two-tailed repeated-measures t-tests to determine whether

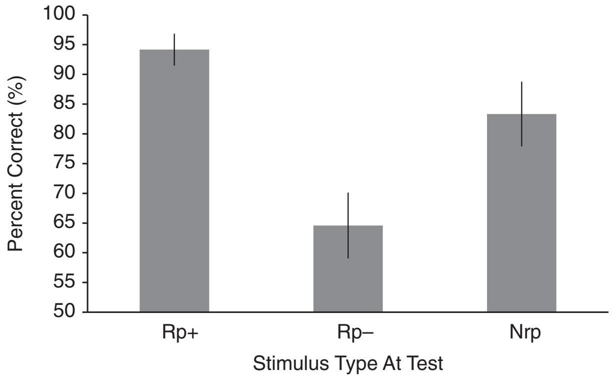

Figure 2. Accuracy of the responses to the memory test items in the test phase of Experiment 1. Rp+ refers to items that were recognized during the practice phase (e.g., the bright red car). Rp− refers to items that belong to practised categories (e.g., muffins) but this specific item was not practised (e.g., this particular chocolate chip muffin was not practised). Nrp means this entire category of items (e.g., baskets) was not practised. The error bars in this and subsequent figures show the 95% within-subjects confidence intervals as described by Cousineau (2005).

there was a benefit of recognition practice (Rp+ > Nrp) or any cost related to nonpractised items (Rp− < Nrp). The same follow-up *t*-tests examined any difference between correct rejection rates for test lures from a practised category versus test lures from a nonpractised category. The instructions to the participants stressed accuracy and not speed. However, we analysed the data for evidence of a speed–accuracy tradeoff and found no such evidence.

Results

Recognition-induced forgetting: An analogue to canonical retrieval-induced forgetting. The mean accuracy of participants' old-versus-new judgements across the types of test objects is shown in Figure 2. These means show that participants were highly accurate at reporting that the practised items (Rp+) were old. However, recognition practice hurt participants' ability to recognize an item initially studied, but not practised during the recognition-practice phase (Rp−) relative to those in which no exemplars from the category were practised (Nrp). These findings resulted in a significant main effect of trial type in the ANOVA, $F(3, 57) = 52.72$, $p < .001$. Recognition practice aided later recognition of Rp+ items (94%) relative to Nrp items (83%), $t(19) = 3.73$, $p = .001$. Recognition practice hurt later recognition of Rp− items (65%) relative to Nrp items (83%), $t(19) = 6.96$, $p < .0001$. These two comparisons mirror the pattern observed using recall of verbal information in typical retrieval-induced forgetting paradigms.

Correct rejection of test lures. Test lures from nonpractised categories (91%) were not significantly better identified as new relative to test lures from practised categories (91%), $t(19) = 0.30$, $p = .766$. To provide another way of quantifying this null finding, we calculated the JZS Bayes Factor (as specified in Rouder, Speckman, Sun, Morey, & Iverson, 2009). This analysis indicated that the null hypothesis is approximately 5.61 times more likely than the alternative hypothesis that recognition differed across these types of test items. This shows that participants were just as accurate at identifying an item as new when it belonged to a practised category as when it belonged to a nonpractised category.

Discussion

Experiment 1 establishes that a memory impairment, like retrieval-induced forgetting, is observed when subjects remember real-word objects and recognize a subset of those objects before an ultimate memory test. Moreover, by using real-world objects, we were able to determine whether this memory impairment spread to representations in the same semantic category as the nonpractised item or whether the benefit of recognition practice spread to representations in the same semantic category as the practised items. There was no evidence of this type of interaction between new exemplars within the same category. This finding supports the third hypothesis described earlier that neither the costs nor the benefits of recognition-induced forgetting spreads to new, semantically related exemplars. This is an observation that has not been possible to make in previous work relying on retrieval of verbal representations.

EXPERIMENT 2

Typical verbal long-term memory experiments of retrieval-induced forgetting utilize word-stem completion tasks to test memory. This inherently requires participants to remember exemplars as members of larger semantic categories, such as remembering orange as a fruit to complete the word stem FRUIT: or_____. However, the visual stimuli in our paradigm are presumably stored in visual long-term memory and a verbal naming strategy may not be required. In fact, in Experiment 1 we found no difference between correct rejections to test lures from practised and nonpractised categories. This lack of effect on new objects suggests that this memory impairment is specific to the stimuli encoded and not reflective of the general semantic structure of memory. However, it is also possible that subjects in Experiment 1 were naming the objects they saw at study and recognition practice, such that the effects we observed were due to the nature of their verbal naming and not the storage of visual representations (see Lupyan, 2008a, 2008b, for examples of verbal naming strategies affecting visual memory). In other words, it is possible that the object-specific recognition-induced forgetting in Experiment 1 was due to participants spontaneously naming the objects with highly specific verbal labels (e.g., chocolate chip muffin with no paper wrapper). This could lead to a specificity of the memory representation even without relying on storage of representations in an analogue visual format. If this were the case, preventing such highly specific labelling by instructing subjects to name the objects at either at a basic level (e.g., muffin) or a superordinate level (e.g., food), should eliminate the specificity of the recognition-induced forgetting to the particular objects that we observed in Experiment 1. Thus, the goal of Experiment 2 was to rule out the possibility that the pattern of effects in Experiment 1 was due to a highly specific naming strategy that the subjects may have covertly carried out, rather than an object-specific visual memory effect.

We tested whether a verbal naming strategy was the source of the effects we observed in Experiment 2 by instructing participants to verbally name the objects during the study phase at different levels of categorization. Participants in Experiment 2 were either instructed to categorize and verbally name the objects according to their basic-level category (e.g., bike, muffin, jacket, goggles) or to categorize and verbally name objects according to a superordinate-level category (e.g., food, clothes, etc.). If the memory effects in Experiment 1 were object specific because of the nature of subjects assigning each exemplar a highly specific verbal label, then we should see evidence for recognition-induced forgetting, and the equivalent correct rejection rates across test lures from practised and nonpractised categories, eliminated in Experiment 2.

Method

Participants. Twenty-four naïve observers participated in Experiment 2 in exchange for course credit. The screening criteria were identical to Experiment 1.

Stimuli and procedures. All methods were identical to Experiment 1, except as follows. Stimuli were drawn from a new set of 12 categories of objects, with 15 exemplars in each category. Half of the participants were randomly assigned a basic-level naming task during the study phase. In the basic-level naming task, participants were instructed to verbally name the category of the object when it appeared on the screen. They were presented with the names of all possible categories on an instruction screen before the study session (i.e., muffin, goggles). There were 12 categories with six exemplars in each. The other half of the participants were assigned a superordinate-level naming task during the study phase. In the superordinate-level naming task, participants were instructed to verbally name whether an object was an item that one could wear (by stating "wear") or an item that one could not wear (by stating "not wear") when it

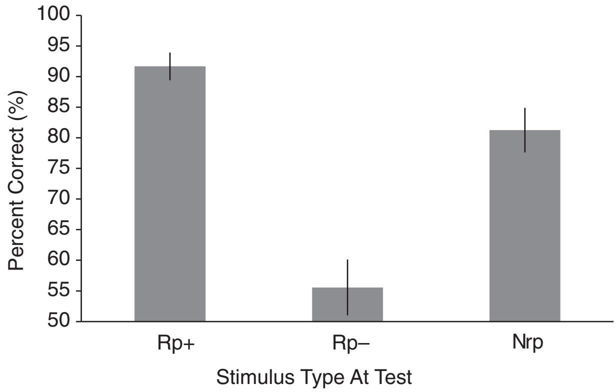

Figure 3. Accuracy of the responses to the memory test items in the test phase of Experiment 2 by participants in the basic-level naming group.

appeared on the screen. Half of the objects were "wear" objects and half of the objects were "not wear" objects. Compliance with this task was monitored by an experimenter seated behind the participant in the same room.

Results

Recognition-induced forgetting. The mean accuracy across the types of test objects from Experiment 2 is shown in Figures 3 and 4. Across both naming conditions in Experiment 2, we replicated the pattern of results from Experiment 1. In the basic-level naming group (Figure 3), recognition practice aided later recognition of Rp+ items (92%) relative to Nrp items (81%), $t(11) = 3.04$,

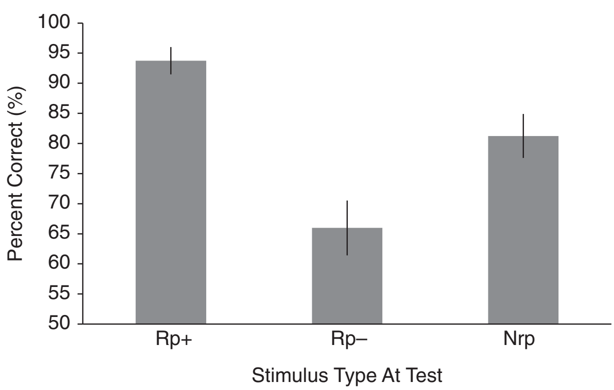

Figure 4. Accuracy of the responses to the memory test items in the test phase of Experiment 2 by participants in the superordinate-level naming group.

p = .011 and hurt later recognition of Rp− items (56%) relative to Nrp items (81%), $t(11)$ = 3.64, p = .004. In the superordinate-level naming group (Figure 4), recognition practice aided later recognition of Rp+ items (94%) relative to Nrp items (81%), $t(11)$ = 3.76, p = .003 and hurt later recognition of Rp− items (66%) relative to Nrp items (81%), $t(11)$ = 4.00, p = .002. We entered the accuracy data into a mix model ANOVA with the between-subjects factor of naming condition (basic versus superordinate level) and the within-subjects factor of trial type (Rp+, Rp− versus Nrp). The main effect of trial type was significant, $F(2, 22) = 64.29$, $p < .0001$, replicating the forgetting triggered by recognition practice in Experiment 1. However, we observed neither a main effect of naming condition, $F(2, 22) = 1.31$, $p > .25$, nor the interaction of Trial type × Naming condition, $F(2, 22) = 1.17$, $p > .30$. Moreover, the naming task did not change the specificity of the memory impairment for Rp− or Nrp items, indicating that the visual stimuli themselves induced this type of specific memory impairment and not a verbal strategy that the participants might have concurrently engaged.

Correct rejection of test lures. In the basic-level naming group, we found no reliable difference between correct rejection of test lures from nonpractised categories (83%) relative to test lures from practised categories (89%), $t(11)$ = 1.86, p = .090, and a JZS Bayes Factor of 1.11. In the superordinate level naming group, we again found no reliable difference between correct rejection of test lures from nonpractised categories (82%) relative to test lures from practised categories (88%), $t(11)$ = 1.90, p = .084, and a JZS Bayes Factor of 1.05. Although these findings generally replicate those from Experiment 1, we describe how they motivate Experiment 3 in the next section.

A mixed model ANOVA with naming group (basic level, superordinate level) as the between-subjects factor and category (test lures from nonpractised categories, test lures from practised categories) as the within-subjects factor yielded neither a significant main effect of category, $F(1, 22) = 1.26$, p = .273, nor an interaction of naming condition, $F(1, 22) = 0.99$, p = .331. Replicating Experiment 1, this shows that participants were just as accurate at identifying an item as new when it belonged to a practised category as when it belonged to a nonpractised category. These results support the hypothesis that neither the costs nor the benefits of recognition-induced forgetting spreads to new, semantically related exemplars, even when a basic-level or superordinate-level verbal naming strategy is implemented.

Discussion

Verbally labelling objects as belonging to either a basic-level or superordinate-level category during study did not affect the memory impairment, suggesting it is the visual stimuli themselves that induce the specificity of the recognition-induced forgetting effects we observed in Experiment 1. We found a similar relationship across Rp+, Rp−, and Nrp objects recognition memory performance in Experiment 2 as Experiment 1 despite these naming conditions. These findings are inconsistent with the explanation that a verbal naming strategy during study is the source of the recognition-induced forgetting. In addition, this experiment replicated the support from Experiment 1 for the hypothesis that new, semantically related exemplars are unaffected by recognition-induced forgetting.

We note that, although the effects of recognition practice were not significant in either of the naming groups of Experiment 2, these means appear to show a trend towards better performance for the test lures of the practised categories. Indeed, the Bayes Factor analyses suggest approximately equal evidence for no difference versus a difference between the types of test lures. This suggests that there may have been a weak benefit that spread to other category members. This could be due to the subjects' verbal-naming task eliciting this spreading effect within category, perhaps on a subset of trials or driven by a subset of the subjects. This equivocal evidence from Experiment 2 helped motivate our more aggressive manipulation of verbal behaviour in Experiment 3.

EXPERIMENT 3

The goal of Experiment 3 was to further test our assumption that the recognition-induced forgetting effects we found earlier are visual in nature and not due to verbal processing. The evidence from Experiments 1 and 2, suggesting that this memory impairment is object specific, is surprising because the general understanding of information in long-term memory is that it is stored semantically. In Experiment 3 we sought to ensure that the object-specific memory impairment demonstrated previously is visual in nature. This is particularly relevant given the trends we saw in Experiment 2. When the subjects of Experiment 2 engaged in a basic (e.g., muffin) or superordinate (e.g., food) naming task, we found a trend towards spreading of the recognition-practice effects to items from the same category (i.e., muffins). This means that the absence of such spreading in Experiment 1 might be explained by a more specific verbal naming strategy for the items (e.g., chocolate chip muffin with no paper wrapper) spontaneously used by the subjects in that experiment. In Experiment 3, we eliminated all verbal encoding during the recognition-practice phase with an articulatory suppression task to rule out the possible strategy that participants were verbally recoding practised objects.

Method

Participants. Twelve naïve observers participated with the same screening criteria used in Experiment 1. Participants were compensated with a $10 gift card for participation.

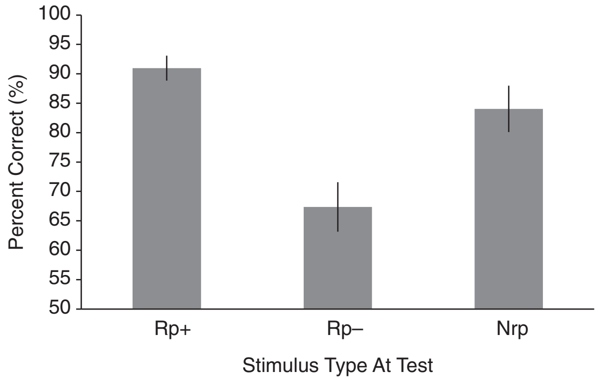

Figure 5. Accuracy of the responses to the memory test items in the test phase of Experiment 3.

Stimuli and procedure. All methods were identical to Experiment 1, unless otherwise noted. During the entire recognition-practice phase participants were instructed to verbally repeat the word "the" at a rate of 3–4 times per second. This articulatory suppression task has been shown to prohibit verbal encoding (Baddeley, 1986). Compliance with this task was monitored by an experimenter seated behind the participant in the same room.

Results

Recognition-induced forgetting. The mean accuracy of participants' old-versus-new judgements across the types of test objects is shown in Figure 5. Replicating the previous experiments, participants were highly accurate at reporting that the practised items (91%, Rp+) were old. Recognition practice reliably hurt participants' ability to recognize an item initially studied, but not practised during the recognition-practice phase (67%, Rp−) relative to those in which no exemplars from the category were practised (84%, Nrp), $t(11) = 2.92$, $p = .014$.

To determine if the concurrent articulatory suppression task used here significantly affected the recognition-induced forgetting effects we observed in Experiment 1, we entered the between-experiments accuracy data from Experiment 1 and Experiment 3 into a mix model ANOVA with the between-subjects factor of verbal load condition (no verbal load in Experiment 1 versus a verbal load in Experiment 3) and the within-subjects factor of trial type (Rp+, Rp− versus Nrp). The main effect of trial type was significant, $F(2, 60) = 51.61$, $p < .001$. However, we observed neither a main effect of verbal load, $F(1, 30) = 0.001$, $p = .974$, nor an interaction of the factors, $F(2, 60) = 0.647$, $p = .527$.

Correct rejection of test lures. Again replicating the previous two experiments, we found that test lures from nonpractised categories (83%) were not significantly better identified as new, than test lures from practised categories (87%), $t(11) = 1.02$, $p = .331$. The JZS Bayes Factor for this comparison was 3.00, indicating that the null hypothesis is three times more likely than the alternative. This shows that participants were just as accurate at identifying an item as new when it belonged to a practised category as when it belonged to a nonpractised category, further supporting the hypothesis that neither the costs nor the benefits of recognition-induced forgetting spread to new, semantically related exemplars.

Discussion

Replicating Experiment 1 with an articulatory suppression task during the recognition-practice phase, we found no effect on the observed memory impairment. These results, combined with the results from Experiment 2, clearly demonstrate that the recognition-induced forgetting found in the present study is independent of a verbal strategy. In addition, the results from Experiment 3 provide yet another replication of the pattern of findings from Experiments 1 and 2, showing that recognition-induced forgetting does not influence memory for novel semantically related exemplars.

GENERAL DISCUSSION

The goal of the present paper was to examine how accessing visual information in long-term memory affects the other visual memory representations learned at the same time, as well as correct rejections of new objects from the same semantic category that were never seen prior to the final test. We accomplished this through a modified retrieval-induced forgetting paradigm in which we examined the presence of a visual recognition-induced memory impairment. The results were consistent with classic retrieval-induced forgetting experiments using verbal stimuli (e.g., Anderson et al., 1994). Participants easily remembered practised items (Rp+) and had more difficulty with items that were not practised, but belonged to practised categories (Rp−), relative to items from nonpractised categories (Nrp). Our evidence demonstrates that recognition-induced forgetting does exist for detailed, real-world visual information stored in long-term memory.

The real-world stimuli that we used in the present study allowed us to examine the extent to which this memory impairment of nonpractised exemplars affects a range of visual object representations from the practised category. Across all three experiments, we found that the memory impairment only affected representations of items the participant had previously viewed. This restrained, object-specific memory impairment in long-term memory suggests that recognizing visual information from long-term memory is tightly focused and that any costs or benefits of recognizing information do not spread to other visual representations in a category (see Guerin, Robbins, Gilmore, & Schacter, 2012, for evidence of a similar object-specific memory).

How do our findings relate to expectations of inhibition operating in long-term memory? In our study, new items from the same semantic category would presumably serve as the neighbouring nodes described in the priming literature (McKoon & Ratcliff, 1992; McNamara, 1992a, 1992b), but we do not find evidence for impaired memory of them. We only find a memory impairment for items from the same category that are presented during the experiment. This finding is even more unexpected given the widely accepted view that information stored in long-term memory is generally stored in a semantic structure regardless of the modality of encoding. Semantic storage in long-term memory certainly would predict lures from the same semantic category to show some inhibition (such as in Konkle et al., 2010), as well as more inhibition for lures from practised categories relative to lures from nonpractised categories. We do not find evidence for such spreading inhibition in either of these cases (see also Huber, Shiffrin, Lyle, & Quach, 2002; Huber, Shiffrin, Lyle, & Ruys, 2001; Shiffrin, 2003). Instead, our findings support the view that visual long-term memory storage is different from the storage of information from other modalities. The present results align more with perceptual-identification priming, which relies on low-level visual processes and not a semantic network. Perceptual priming has been divorced from semantic priming assessed with word-stem completion in studies using amnesic patient HM, based on evidence that his condition disrupted priming measured with word-stem completion but not perceptual priming (Postle & Corkin, 1998). The findings of this paper of course suggest that there is some semantic relationship among items stored in VLTM in this paradigm because the basic effect is due to membership in a particular semantic category (e.g., nonpractised apples are worse than practised apples). The goal of potentially teasing apart the role of low-level perceptual priming and higher-level semantic priming creates an important prediction for future work, namely whether this effect will occur for perceptually similar items like a red apple and a red balloon.

In conclusion, visual recognition-induced forgetting does exist for items in visual long-term memory. The impaired memory of items found in our study is object specific, such that only nonpractised items shown in the experiment belonging to practised categories were impaired, not all semantically related items. These findings have important implications for real-world visual long-term memory tasks, such as those of critical importance in the justice system. Our findings suggest that the act of recognizing one piece of information from our memory after seeing a crime can interfere with our memory of the other objects we viewed at that time. For example, recognizing a bank robber in a line-up can selectively interfere with our ability to accurately recognize other people from the scene, like the driver of the get-away car. However, our findings also suggest that recognition of the incorrect information (i.e., correctly rejecting innocent people in the line-up) will not be impaired.

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