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Activating learned exemplars in children impairs memory for related exemplars in visual long-term memory

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A popular educational method when teaching children new information is encouraging children to activate previously learned information held in long-term memory. A potential downside of this practice is the considerable evidence that there are negative consequences of accessing long-term memory representations. Specifically, it has been shown that accessing information in long-term memory can actually impair related memories. This impairment has classically been demonstrated with verbal material (i.e., retrieval-induced forgetting) and more recently with visual material in adults (i.e., recognition-induced forgetting). The goal of the present study was to examine whether recognition-induced forgetting exists in visual long-term memory for children aged 6–10 years old, the age at which retrieval-induced forgetting appears to emerge. To this end, we presented children with an abbreviated, age-appropriate recognition-induced forgetting paradigm. If children suffer recognition-induced forgetting, practicing a subset of objects from a category of objects will impair memory for the other, non-practiced objects from the same category. The results showed that children across all ages showed impaired memory for non-practiced objects from practiced categories and no benefit from recognition practice for the younger children. These

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findings show that children's visual long-term memory is vulnerable to recognition-induced forgetting and does not appear to benefit from recognition practice.

Keywords: Recognition-induced forgetting; Visual long-term memory; Developmental recognition-induced forgetting; Recognition; Retrieval-induced forgetting

Encouraging children to activate learned exemplars stored in long-term memory (often referred to as *prior knowledge*) is a popular educational method used to facilitate learning of new information (Fisher & Frey, 2009). This practice seems contrary to the considerable evidence that there are negative consequences of accessing long-term memory. The hallmark demonstration that accessing representations in memory can actually impair related memories is called retrieval-induced forgetting (Anderson, Bjork, & Bjork, 1994). In their clever paradigm, Anderson and colleagues presented participants with a list of word pairs to study for a later test (e.g., FRUIT:banana, SPORT:tennis, FRUIT:apple). Then during a practice phase, participant's memory for a subset of these pairs was tested using a word stem completion task (e.g., FRUIT:ba____). This practice phase created three classes of items: (1) those that were practiced (e.g., banana), (2) those that belonged to practiced categories but were not themselves practiced (e.g., apple) and (3) those that belonged to categories that were not practiced (e.g., tennis). In a final test phase, participant's memory for items from all three categories was tested. Memory was best for items from the first category, the practiced items. Interestingly, participants were significantly worse at remembering items that belonged to the second category relative to the third category. The second and third classes of items were both comprised of items that were shown once during the study phase and not practiced. They only differed in whether they belonged to a practiced category. Therefore it was this difference in category membership that caused a reliable difference in memory for these items. The items that did belong to a practiced category were forgotten, hence the term *retrieval-induced forgetting*. This finding has been extensively studied and replicated (see Murayama, Miyatsu, Buchli, & Storm, 2014 for a review).

If children suffer retrieval-induced forgetting, this would cast doubt on the efficacy of activating learned exemplars (i.e., items in long-term memory) as a useful instructional method to facilitate learning (Fisher & Frey, 2009) as described above. Indeed a number of studies have examined retrieval-induced forgetting in children (Aslan & Bäuml, 2010; Conroy & Salmon, 2005; Ford, Keating, & Patel, 2004). These studies support the proposal that retrieval-induced forgetting develops around the age of school entry. Specifically, Aslan and Bäuml (2010) found retrieval-induced forgetting to be present in second graders and absent in kindergarteners. In addition, Ford and colleagues (2004) found retrieval-induced forgetting in first graders.

Proposals about the presence of retrieval-induced forgetting in educational contexts have cited the considerable amount of work examining the boundary conditions of retrieval-induced forgetting (see Anderson & Bell, 2001; Anderson & McCulloch, 1999; Chan, 2009; Chan, McDermott, & Roediger III, 2006; García-Bajos & Migueles, 2003, 2013; Storm, Bjork, & Bjork, 2012) in suggesting that there may be no simple conclusion regarding the presence and role of this memory impairment in school settings (e.g., Carroll, Campbell-Ratcliffe, Murnane, & Perfect, 2007). One possible reason such real-world applications of this memory impairment in children is complicated to assess may be because the impairment only pertains to verbal items and not visual (pictorial) items. Specifically, evidence of incredibly accurate recognition memory for objects in visual long-term memory (Brady, Konkle, Alvarez, & Oliva, 2008; Standing, 1973), suggests that memory for visual objects in children may be sufficiently robust to be immune to retrieval-induced forgetting. If this memory impairment does not spread to information presented pictorially in children, they may overcome retrieval-induced forgetting in educational settings using visual long-term memory.

Examining visual long-term memory impairments in children is particularly important for three reasons. First, visual representations are especially useful for storing a plethora of information relevant to children. Representations that do not easily lend themselves to storage in a visual format are generally higher-level concepts (e.g., “democracy”, “federalism”) than concepts young children are learning (e.g., “egg”, “chick”). Second, the notion of visual learners, or people who have a visual learning style, has long-standing popularity despite the lack of scientific evidence supporting learning styles (Pashler, McDaniel, Rohrer, & Bjork, 2008). This common misconception continues to lead many children to be taught primarily using visual information (e.g., images, pictures, colour, maps and other visual media). Third, the significant use of catering instruction to the visual modality extends well beyond the misconception of learning styles. Educators may present information visually for valid reasons, such as maintaining student’s interest or providing modality-specific skills.

The retrieval-induced forgetting studies with children reviewed above did not examine recognition-induced forgetting with a restricted set of stimuli that focuses on the visual modality (e.g., Aslan & Bäuml, 2010; Ford et al., 2004). This limits their conclusions to the retrieval of semantic long-term memory. While semantic memory has generally been thought to be modality independent (Bransford & Franks, 1971; Gernsbacher, 1985), information can also be stored in long-term memory with modality specificity, such as auditory (Dodson & Shimamura, 2000) or visual representations (Brady et al., 2008; Standing, 1973). Specifically, Standing (1973) has demonstrated that memory for pictures is better than memory for words. In addition, practice remembering items in previous studies of this memory phenomenon have used retrieval, a process which has historically been viewed as due to different memory processes than recognition. For example, a major class of theoretical models describing recognition memory, single process models, assumes a process by which the test item serves as a cue directly accessing a familiarity signal (e.g., Dunn, 2004; McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997). Recognition has typically been considered easier than recall, successfully accomplished with weaker representations (e.g., Kahana, Rizzuto, & Schneider, 2005). Thus, impaired recognition memory induced by recognition practice (Maxcey & Woodman, 2014) appears contrary to the typical assumption that access to a memory representation during recognition is direct and uncomplicated. Given that evidence of recognition-induced forgetting is a novel and surprising finding, existing work on retrieval-induced forgetting in children cannot speak to whether we will find evidence of recognition-induced forgetting in children.

Here we tested the hypothesis that visual long-term memory in children is prone to recognition-induced forgetting. Support for this hypothesis would suggest that children suffer from visual recognition-induced forgetting, as do adults (Maxcey & Woodman, 2014), adding to existing evidence of verbal-semantic memory impairments in both children (e.g., Ford et al., 2004) and adults (e.g., Anderson et al., 1994). Such an outcome would indicate that retrieval-induced forgetting cannot be overcome by presenting the same information visually.

In the present study, we employed an abbreviated recognition-induced forgetting paradigm (Maxcey & Woodman, 2014) to test the hypothesis that visual long-term memory in children is prone to recognition-induced forgetting. In the recognition-induced forgetting paradigm, stimuli are pictures of real-world objects rather than words. Participants are initially exposed to a series of objects during the study phase, as shown in Figure 1. These objects are exemplars from categories (e.g., multiple different pictures of butterflies). During the middle recognition-practice phase, participants are simultaneously shown two objects from the same category and asked which one they saw during the study phase. In the test phase, participants are sequentially presented with objects subdivided into recognition-practiced objects (practiced objects[1]), non-practiced objects from recognition-practiced categories (related objects), and objects from non-practiced categories (baseline objects), and asked if they have ever seen each object during any phase of the experiment. Maxcey and Woodman (2014) found the typical pattern of retrieval-induced forgetting in this recognition-induced forgetting paradigm, with a benefit of practice measured by increased memory for

[1]Note that for the sake of accessibility to the reader, here we revise the nomenclature used in our previous recognition-induced forgetting paradigm (Maxcey & Woodman, 2014) by using the term “practiced objects” to refer to objects that were previously denoted “Rp+ items”, “related objects” to refer to objects previously denoted “Rp- items” and “baseline objects” to refer to objects that were previously called “Nrp items”.

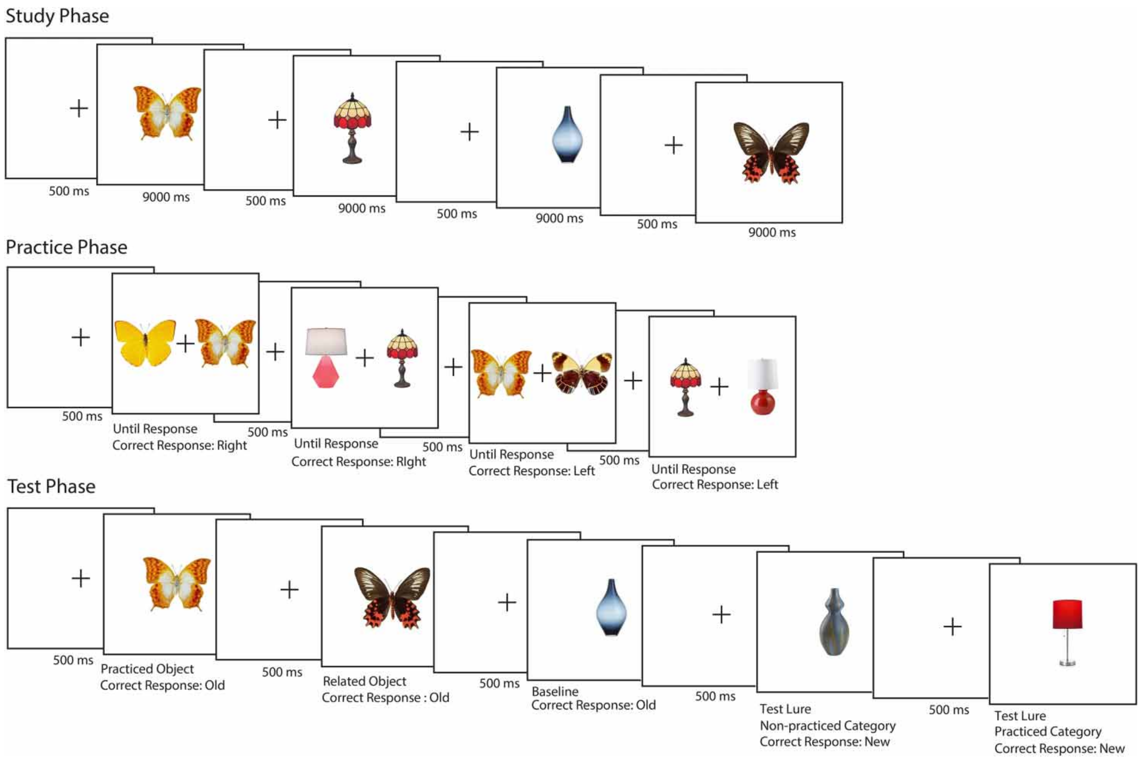

Figure 1. Example of the stimuli and procedure. The study phase consisted of 42 items presented sequentially for nine seconds interleaved by a 500 ms fixation cross. Children were instructed to study the visual details of each image for a later memory test. Then, during the recognition practice phase, participants were shown half of the items from half of the categories from the study phase, paired with another exemplar from the same category. Children responded by button press to indicate which item (the item on the left or right) was the item they studied in the previous phase. Finally, in the test phase, children responded whether they had seen the exact exemplar at any point in the experiment. Practiced refers to items that were practiced during the recognition practice phase (e.g., orange butterfly with white in the middle). Related refers to items that belong to practiced categories (e.g., brown and orange butterfly with orange on the bottom) but this specific item was not practiced. Baseline means this object was drawn from a category of items (e.g., vases) that was not practiced. Test lure refers to objects that warrant a "new" response.

practiced objects relative to memory for baseline objects and forgetting measured by poorer memory for related objects relative to memory for baseline objects. In the present study, we expected that children would also show the typical cost for related objects and benefit for practiced objects of recognition-induced forgetting because previous research has supported the proposal that such memory impairments emerge at this age (Aslan & Bäuml, 2010; Ford et al., 2004).

METHOD

Participants

Participants were forty-eight children from Manchester Community Schools. The children were recruited by a letter to their parents or guardians that was sent home to every first, second, third and fourth grade child in the Manchester Community Schools district in North Manchester, Indiana. The children who participated in this study were in age-appropriate grades and from a variety of different classrooms across these grades. The children aged 6–10 years old with a mean age of 7.8. This age group was selected because previous work suggests memory impairments emerge around the age of school entry (Aslan & Bäuml, 2010; Conroy & Salmon, 2005; Ford et al., 2004). Three children (two six-year-olds, one eight-year-old) were excluded from analysis for pressing the same button on every trial in the test phase. The remaining 45 children included five six-year-olds, 17 seven-year-olds, nine eight-year-olds, eight nine-year-olds, and six 10-year-olds. Participants passed the Ishira colour blindness test. Parents or guardians reported the children had normal or corrected-to-normal vision, provided informed consent and were compensated with a US$10 gift card. Children received an age appropriate book.

Stimuli

Stimuli were presented on a flat-screen 16 inch CRT monitor using E-prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2012). A viewing distance of 80 cm was controlled by a forehead rest. Stimuli were drawn from a set of real-world objects (Brady et al., 2008, available at http://cvcl.mit.edu/MM/objectCategories.html) and public domain images (Google Images http://images.google.com), subdivided into eight categories, six categories with 15 exemplars and, to protect against primacy and recency effects, two categories with six exemplars (see Procedure section). Stimuli were viewed on a white background, subtending 9.44° × 7.13° degrees of visual angle.

Procedure

We used the procedure of Maxcey and Woodman (2014) with a few exceptions designed to adapt the method to be suitable for children. An example of the stimuli and procedure is shown in Figure 1. During the initial phase, the study phase, participants were shown one object at a time on the screen for nine seconds, interleaved by a 500 ms centre fixation cross, until 42 objects had been randomly presented. Objects were randomly selected and belonged to six categories (e.g., butterfly) with six exemplars in each category. Participants were instructed to study the visual details of these objects for a later memory test. They were told that the test would require visual memory as detailed as "this specific red bike with a banana seat"; therefore simply remembering the category "bike" would not help at test.[2] To minimize the influence of primacy and recency effects (Murdock, 1962), the first and last three objects belonged to two additional categories that were not analyzed.

The purpose of the intermediate phase, the recognition-practice phase, was to practice participants on recognizing half of the objects from half of the categories they were shown in the study phase. In the recognition-practice phase participants practiced recognizing three objects from three categories, or nine total objects. Each practiced object was shown twice and was paired with a new practice lure from the same category on each trial, totalling 18 randomly presented trials. The specific object categories practiced were counterbalanced across subjects, such that the images that were the practice lures for some participants were equally often the studied objects for other participants. Participants were shown two objects at a time on the screen, one on the left and one on the right. Participants were instructed to determine which of the objects they had seen before and respond with a two-alternative-forced-choice button press using their right hand. They pressed the left key on the response box with their index finger if the object from the study phase was on the left, and the right key on the response box with their middle finger if the object 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 the recognition practice phase, participants completed a five-minute distractor task during which they played tic-tac-toe with the experimenter.

During the final phase, the test phase, participants were shown one object at a time and asked to report whether they had *ever* seen the exact image previously at any point in the experiment. 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". These images fell into four categories. In three of the categories the objects were old, warranting a "yes" response: (1) practiced objects were shown both during the study phase and practiced in the recognition-practice phase, (2) related objects were shown during the

[2]One concern might be that participants were relying on verbal long-term memory to complete this task. However, previous work using this recognition-induced forgetting paradigm has shown that verbal coding of the stimuli cannot explain the forgetting effects (Maxcey & Woodman, 2014). When subjects are required to verbally recode the visual stimuli according to instructions, the pattern of the effects across the types of trials was identical.

study phase and then were *not* practiced in the recognition-practice phase but their category was practiced (e.g., butterflies were practiced but not that specific butterfly), (3) baseline objects were shown during the study phase and then were *not* practiced in the recognition-practice phase and their category was *not* practiced (e.g., a vase and vases were not practiced). The fourth category consisted of new objects, warranting a "no" response: (4) test lures were objects that were never seen before in the experiment. Test lures were drawn from the same categories as the objects during the study phase, such that half of the test lures belonged to practiced categories and half belonged to non-practiced categories.

At test "no" and "yes" responses were equally probable. The test trial distribution consisted of (1) two practiced and two related objects from each of the three practiced categories (2) two baseline objects from each of the three non-practiced categories and (3) three test lures from each of the six categories. Therefore, half of the objects in the memory test were previously shown (18 total practiced, related and baseline objects) and half of the objects were not previously shown (18 total test lures). All objects were randomly presented during test, regardless of their membership in any of these types of trials. Practice lures from the recognition practice phase were never included in the test phase.

Data analysis

The primary dependent variable for our recognition data was accuracy in terms of percent correct (i.e., hits for practiced, related, and baseline objects, and correct rejections for test lures). We found the same pattern of results when we computed *A'* (Snodgrass, Levy-Berger, & Haydon, 1985) and B''_D (Donaldson, 1992) and include the results of those analyses as well. We used within-subjects analysis of variance (ANOVA) and an alpha level of $p = .05$ for the omnibus test. Preplanned, two-tailed repeated measures *t*-tests were used to determine whether there was a benefit of recognition practice (% hits for practiced objects >% hits for baseline objects) or any cost related to non-practiced objects (% hits for related objects <% hits for baseline objects). The same follow-up *t*-tests examined any difference between correct rejection rates for test lures from practiced versus non-practiced categories (% correct rejections for test lures from practice categories ≠% correct rejections for test lures from non-practiced categories). All *t*-tests are accompanied by measures of Cohen's *d* effect size. To provide a way of quantifying the support for the null hypothesis, we calculated the JZS Bayes Factor[3] (as specified in Rouder, Speckman, Sun, Morey, & Iverson, 2009).

[3]The JZS Bayes Factor gives an indication of the strength of the alternative relative to the null hypothesis. A JZS Bayes Factor value of 1–3 is considered anecdotal evidence for the null hypothesis, while a value greater than 3 is considered substantial evidence for the null hypothesis.

RESULTS

The mean accuracy of participants' old versus new judgements across the types of test objects is shown in Figure 2. Corresponding *A'* and B''_D[4] metrics are presented in Figure 3. These means show that children show the classic recognition-induced forgetting effect. Interestingly, children did not show the typically accompanying benefit of practiced exemplars. These findings resulted in a significant main effect of trial type in the ANOVA, $F(2,88) = 23.44$, $p < .0001$.

Recognition-induced forgetting

Children did show recognition-induced forgetting. This was demonstrated as reliably better performance in identifying baseline objects (78%) relative to related objects (56%), $t(44) = 5.62$, $p < .001$, $d = 1.13$. Memory for related objects (56%) was significantly above chance (50%), $t(44) = 1.97$, $p = .05$, $d = .59$. A correlation revealed no significant relationship between age and cost, $r = +0.231$, $n = 45$, $p = .125$. These results suggest that recognition-practice did indeed hurt later recall of related objects for all ages tested.

Benefit for practiced objects

Overall, participants showed no benefit of practiced objects (80%) over baseline objects (78%), $t(44) = 0.47$, $p = .637$, $d = .09$, and a JZS Bayes Factor of 7.04. This comparison between baseline objects and practiced objects is significant among adults (Maxcey & Woodman, 2014) and is typically interpreted as the benefit of practice in retrieval-induced forgetting and recognition-induced forgetting paradigms.

The failure to find an overall benefit of recognition practice in the final test phase could plausibly be due to chance performance during the intermediate recognition practice phase. To rule out this alternative explanation, we examined performance on the intermediate recognition practice task. Participants selected the correct object during the middle recognition practice phase on 77% of trials. A correlation revealed no significant relationship between age and recognition practice accuracy, $r = +0.242$, $n = 45$, $p = .108$. Thus the children did not lack a benefit for practiced objects at test because they did poorly on the recognition practice task. Indeed, the children performed well above chance in the intermediate recognition practice phase.

[4] B''_D (Donaldson, 1992), indicates a conservative bias with positive values and a liberal bias with negative values. B''_D for practiced, baseline and related objects was –.21, –.06 and .38, respectively. There was a main effect of memory test item on the bias measure B''_D ($F(1,44) = 12.78$, $p < .01$), due to a significant difference between B''_D values for related and practiced objects ($t(44)=5.66$, $p < .001$, $d = 1.72$) and related and baseline objects ($t(44)=4.67$, $p < .001$, $d = 0.67$) that reflected a conservative response bias for related objects.

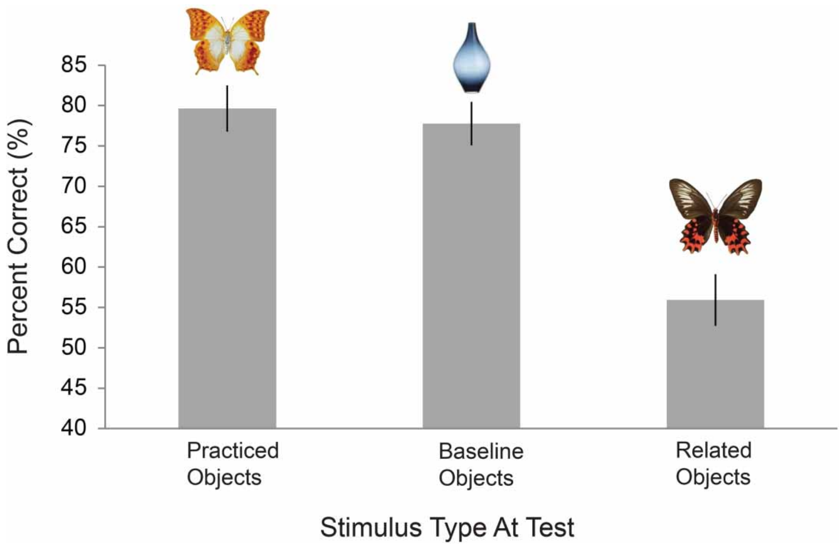

Figure 2. Accuracy of the responses to the memory test items in the test phase. The error bars in this and subsequent figures show the 95% within-subjects confidence intervals as described by Cousineau (2005).

The surprising lack of benefit of recognition practice in the final test phase could also have been driven by age. A correlation revealed a significant relationship between age and benefit for practiced objects, $r = +0.312$, $n = 45$, $p = .037$. This significant positive correlation suggested that the benefit for practiced objects emerged in the older children. Indeed, the average benefit score (% hits for practiced objects) – (% hits for baseline objects) was negative for six-, seven- and eight-year-old participants (–10%, –2%, and –2%, respectively) and positive for nine- and 10-year-old participants (8% and 19%, respectively). Thus the overall null effect on practice was driven by a subsample (nine and 10-year-olds) showing a benefit of practice and the remaining subsample (six- to eight-year-olds) showing a paradoxical inverse effect.

Correct rejection of test lures

In the final recognition test, participants were given an old-new recognition memory test to examine memory for objects they had seen, constructed with 50% new objects and 50% old. This allowed for examination of correct rejections of new objects that belonged either to practiced or non-practiced categories. In analyzing these test lures, we sought to determine whether there was a significant difference between correct rejections to test lures from non-practiced vs. practiced categories, as would be expected if accessing a category resulted in a broad

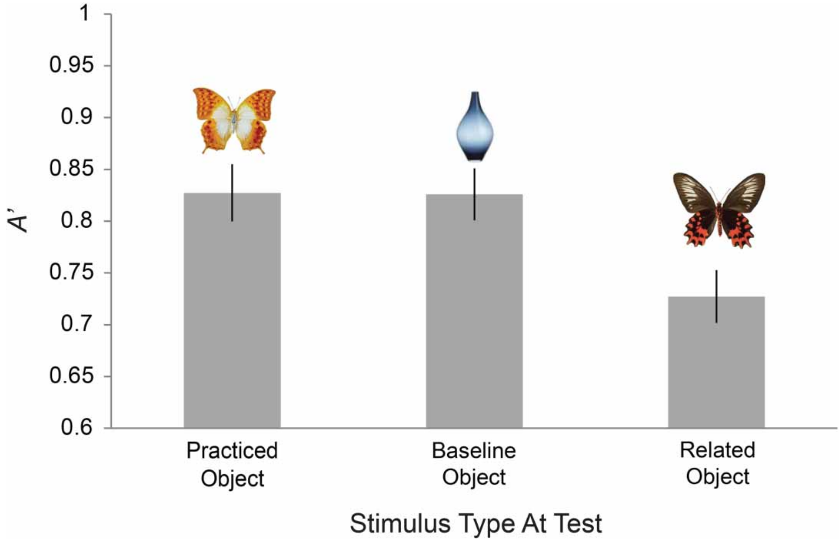

Figure 3. The *A*' metric of discriminability (Snodgrass et al., 1985) of the responses to the memory test items in the test phase. *A*' is a measure non-parametric measure of discriminability, which varies in value from 0 to 1 with a value of .5 indicating chance performance. The corresponding measure of bias, *B"D* (Donaldson, 1992), indicates a conservative bias with positive values and a liberal bias with negative values. *B"D* for practiced, baseline and related objects was –.21, –.06 and .38, respectively.

memory impairment. Figure 4 illustrates the mean accuracy of participants' old versus new judgements across the two types of test lures. We found that correct rejections of test lures from non-practiced categories (71%) were significantly lower than correct rejections of test lures that were members of practiced categories (80%), $t(44) = 3.06$, $p = .004$, $d = .43$. A correlation revealed no significant relationship between age and benefit for rejecting test lures from practiced vs. non-practiced categories, $r = –0.086$, $n = 45$, $p = .575$. These findings indicate that across all ages tested, when children are presented with a new object from a semantic category to which they have previous experience (via recognition practice), they are significantly more accurate at identifying it as novel, compared to a new, object from a semantic category with which they have less experience. This increased ability to correctly reject test lures from practiced categories is the only benefit of practice that was present across all ages tested.

Increased correct rejections to practiced objects in children argue against an alternative explanation of recognition-induced forgetting. Specifically, the structure of recognition practice in the present paradigm requires that each practice trial includes a novel practice lure from the same category which the participant has to select against when reporting which of the two objects on the screen is from the initial study phase. This effectively increases the number of presented

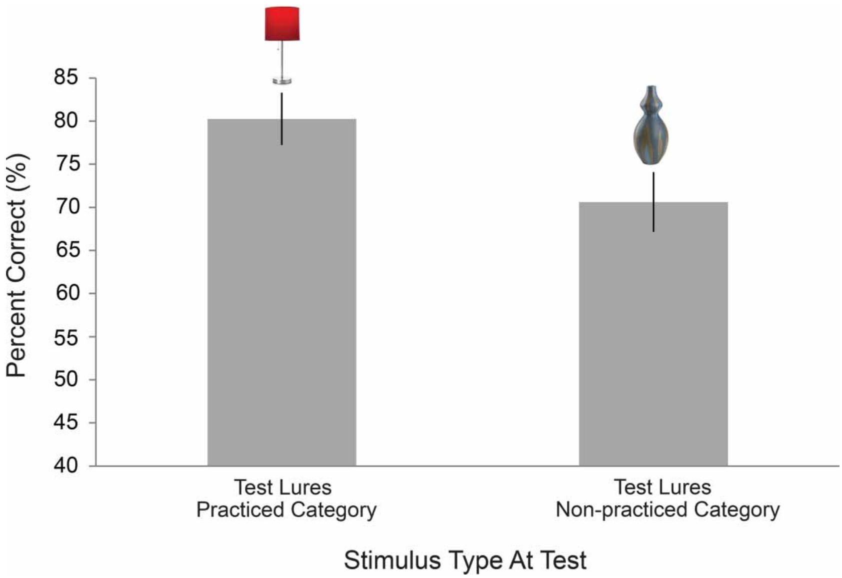

Figure 4. Correct rejections to test lures from practiced and non-practiced categories.

items in practice categories, potentially creating more competitors in memory from practiced categories. This alternative view would argue that such increased competition would decrease the likelihood that an object from practiced categories would be correctly recognized as new or old during the final test phase. However, as reported above, children are reliably better at correctly rejecting test lures from practiced categories relative to test lures from non-practiced categories, ruling out this alternative explanation.

DISCUSSION

The goal of the present study was to test the hypothesis that children are prone to recognition-induced forgetting (Maxcey & Woodman, 2014). In support of that goal, we tested recognition-induced forgetting in children, ages six to 10 years old, an age previously determined to capture the development of similar memory impairments (Aslan & Bäuml, 2010; Conroy & Salmon, 2005; Ford et al., 2004). We predicted that children would show the typical cost associated with recognition-induced forgetting. We found that children of all ages exhibited the cost for non-practiced objects belonging to practiced categories. In other words, objects that were shown only once at the beginning of the experiment, which semantically belonged to practiced categories, were remembered worse than a baseline established with memory for objects that were also shown only once at the beginning of the experiment but did not semantically belong to a category that was practiced.

We also predicted that children would show the typical benefit for practiced objects associated with the recognition-induced forgetting paradigm. Contrary to this prediction, the children did not show the benefit for practiced objects. That is, multiple trials of recognition practice did not benefit memory for practiced objects beyond a baseline level of memory determined by memory for objects shown only once at the beginning of the experiment which were not semantically related to a practiced category.

This result creates an important prediction to test in future work, with an important practical application. That is, if children received more trials of recognition-practice than they did in this experiment, the benefit may occur. This would provide the practical implication that with younger children, more instances of recognition can overcome this predisposition. Interestingly, we did locate the age at which this benefit appeared to begin to emerge for children, ages nine and 10 years old, consistent with work on retrieval-induced forgetting (e.g., Aslan & Bäuml, 2010). Note however that the participant sample was uneven across age groups, so caution must be used in interpreting age-related results.

Taken together, the cost of recognition practice at all ages without the benefit for practiced objects for younger children (ages 6–8) suggest that activating long-term memory representations may only be hurting memory for related information and not helping practiced information. This finding is contrary to the goal of activating background knowledge to facilitate learning. In the present paradigm, the activation of prior knowledge is comprised of long-term memory for specific exemplars. Activating prior knowledge in the classroom may involve broader associations than the exemplars studied herein. It is possible that the memory impairments found in this paradigm do not occur for more elaborately encoded or contextually interrelated information. Indeed, there is evidence that retrieval practice may facilitate memory for non-practiced, organized, textual material (Murayama et al., 2014). However, as discussed above, existing findings from retrieval-induced forgetting studies cannot be applied to the recognition-induced forgetting here without further testing due to large distinctions between retrieval and recognition tasks (e.g., Dunn, 2004; McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997). Since it is possible that the mechanisms that give rise to recognition-induced forgetting operate differently than those that give rise to retrieval-induced forgetting, the present findings indicate a need for further experimentation to determine the impact of recognition-induced forgetting in the classroom.

We next asked whether children would exhibit different rates of correct rejections for test lures belonging to non-practiced and practiced categories. We found that children exhibited reliably fewer correct rejections for test lures from non-practiced categories. These results suggest that while practice did not overtly improve memory for practiced objects relative to baseline for all ages tested, it did have an effect on correct rejections of test lures. Multiple trials of recognition practice did improve the ability to correctly reject a test lure belonging to a practiced category relative to a test lure from a non-practiced category. This improvement in correct rejections seems to be the only benefit for 6–8-year-olds of recognition practice, since memory for practiced objects was not improved (and actually showed a small cost). This analysis of correct rejections was enabled by the unique design of the recognition-induced forgetting paradigm, in which half of the final test items are novel and warrant a "no" response, bolstering the use of our paradigm in assessing memory impairments in future work.

The prominent account of retrieval-induced forgetting is the inhibition account, according to which non-practiced objects from practiced categories are inhibited during practice, explaining the cost for those objects at test (Anderson et al., 1994). Due to children's immature inhibitory control (Bjorklund & Harnishfeger, 1990), it has been thought that children may not show retrieval-induced forgetting. However, the present study adds to existing evidence of memory impairments likely due to inhibition at this age (Aslan & Bäuml, 2010; Conroy & Salmon, 2005; Ford et al., 2004). These results suggest that if the dominant inhibition account is correct, either inhibitory mechanisms driving this effect in visual long-term memory are online before the age of six years old or the type of inhibition involved in these memory impairments is not the same type of inhibition that is developing throughout childhood. Alternatively, the presence of this impairment in 6–10-year-olds, when children are expected to have impaired inhibitory mechanisms (Bjorklund & Harnishfeger, 1990), may indicate that alternate accounts of recognition-induced forgetting need to be explored (e.g., Jonker, Seli, & MacLeod, 2013).

At first look, our finding that children did not show the significant benefit for practiced objects typical of recognition-induced forgetting (Maxcey & Woodman, 2014) appears to be consistent with explanations of retrieval-induced forgetting in terms of reducing the general memory strength of non-practiced objects (Spitzer & Bauml, 2007). According to Spitzer and Bäuml, "retrieval practice does nothing else than reduce unpracticed objects' general memory strength". However, our findings do not support that recognition practice did "nothing else" because we found that recognition-practice had an effect on correct rejections of test lures, an interesting finding uniquely detected with the recognition-induced forgetting paradigm. This lack of benefit for practiced objects, suggests that practicing recognition of visual information may not improve memory for practiced objects, but it does increase children's ability to correctly reject unfamiliar information from practiced categories.

The present evidence of a memory impairment for children using visual stimuli extends current research to suggest that both children and adults exhibit both recognition- and retrieval-induced forgetting (Anderson et al., 1994; Aslan & Bäuml, 2010; Conroy & Salmon, 2005; Ford et al., 2004; Maxcey & Woodman, 2014). This evidence of memory impairments for information in both verbal and visual modalities suggest that instructing to either modality, as in catering instruction to a particular learning style, can have adverse effects. Additionally, retrieval-induced forgetting for verbal information cannot be overcome by presenting the same information visually (pictorially), because, as we have shown herein, children also suffer from visual recognition-induced forgetting.

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