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Recognition-induced forgetting of schematically related pictures

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Abstract

Recognition-induced forgetting is the category-specific forgetting of pictures that occurs when a subset of a category of pictures is recognized, leading to the forgetting of the remaining pictures. We have previously found that recognition-induced forgetting does not operate over categories created by temporal relationships, suggesting this effect does not operate over episodic memory representations. Here we systematically tested whether schematically related categories of pictures are immune to recognition-induced forgetting. We find that sufficiently weak schematically related memories are vulnerable to recognition-induced forgetting. These results offer an alternative interpretation for evidence that recognition-induced forgetting does not operate over episodic memory representations. Evidence that the strength of schematic grouping modulates forgetting supports a model of recognition-induced forgetting in which the key determinant of forgetting is moderate activation. This is the first demonstration that recognition-induced forgetting operates over perceptually distinct objects, demonstrating the ubiquity of recognition-induced forgetting.

Humans automatically form categories consisting of similar objects to simplify the complexity of our visual environment (Croft & Cruse, 2004; Taylor, 2003), increasing the efficiency of perceptual processing and memory storage (Rakison & Oakes, 2003). A *category* refers to a grouping of objects that necessarily share certain features (Corrigan, Eckman, & Noonan, 1989) defined according to perceptual concepts or associative concepts (Zentall, Wasserman, & Urcuioli, 2014). Here we define perceptual concepts formed through inherent physical similarities as encompassing subordinate-level categories (e.g., different types of cockatoos) and basic-level categories (e.g., different types of birds). Associative concepts are formed through experiences and encompass schemas, a single unit in memory that integrates prior knowledge of high-level relationships (e.g., a snake and a cactus are schematically related because they are typical of a desert schema; R. C. Anderson, 1984; Valcke, 2002), as well as superordinate-level categories, objects associated at a high-level taxonomic organization that encompasses lower-level perceptual concepts (e.g., different types of animals)[1]. In other words, schematic knowledge involves the learned relationship between object categories and taxonomic knowledge involves the hierarchical properties of a set of objects, with superordinate category being at the top of the taxonomic hierarchy (Lewis, Poeppel, & Murphy, 2015; Mirman, Landrigan, & Britt, 2017). Despite the potentially distinct underlying neural mechanisms of perceptual and associative concepts (Mack & Palmeri, 2011, 2015; Mareschal, Quinn, Lea, & Lea, 2010), studies investigating forgetting largely ignore these categorical distinctions,

[1]While the development of concepts and category learning are critical to interacting with the world (Sloutsky, 2010), they are beyond the scope of this work.

including our own studies of recognition-induced forgetting[2] of pictures (but see Maxcey, Janakiefski, Megla, Smerdell, & Stallkamp, 2019). Recognition-induced forgetting is the forgetting of objects held in memory following the recognition of a target memory from the same object category (Maxcey & Woodman, 2014)[3]. We have employed the term *object category* in our previous work to broadly apply to both basic- and subordinate-level categories. To generalize across these previous findings, we will use only the term basic-level category to describe the object relationships in the majority of our existing studies (Maxcey, 2016; Maxcey & Bostic, 2015; Maxcey, Bostic, & Maldonado, 2016; Maxcey et al., 2019; Maxcey & Woodman, 2014; Rugo, Tamler, Woodman, & Maxcey, 2017). Here, we test whether recognition-induced forgetting operates across schematically related[4] memories.

Consider the following eyewitness example. If I witness a crime that involves a weapon, getaway car, and a robber, and am then asked by police at the crime scene to identity the robber in a lineup, am I forgetting the weapon and the getaway car? The object relationships in this scenario differ from most studies of recognition-induced forgetting. In this eyewitness example, the objects are meaningfully related because they were encountered at the same time (i.e., temporally grouped) and are associatively

[2]See the General Discussion for a comparison between recognition- and retrieval-induced forgetting.
[3]The recognition-induced forgetting paradigm, by definition, presents additional novel pictures in the old-new recognition judgment task. Our lab has demonstrated that forgetting is not parametrically manipulated by set size, suggesting that forgetting is not due to retroactive interference but is indeed the result of recognition (Maxcey, 2016).
[4]In a previous study (Maxcey et al., 2019) using this level of grouping, we employed the term *superordinate* rather than *schematic*. The types of relationships we test here could also be referred to as *superordinate* at the very abstract level, or as *thematically* related if constrained to objects of different functional roles (Goldwater, Markman, & Stilwell, 2011). Here for the sake of consistency and precision, we use the term *schematic* to describe the association among our stimuli.

grouped by belonging to the schema of *robbery*. If they were grouped at the basic level, like most recognition-induced forgetting studies, the objects would be drawn from the same basic-level category as the target (e.g., they would all be faces, forgetting the face of the getaway car driver after identifying the face of the gunman). It is unknown whether recognition-induced forgetting only operates over such basic-level categories or also applies to schematically related objects.

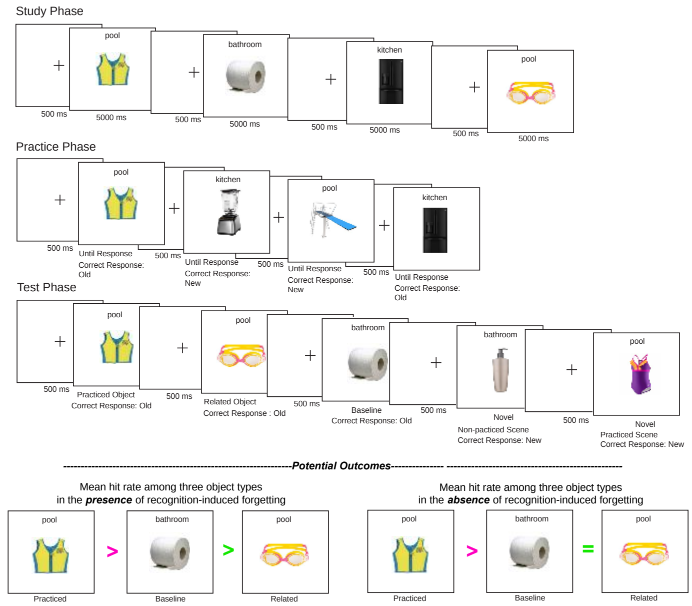

Figure 1. Methods of Experiment 3 from Maxcey et al. (2019). In the study phase, subjects fixated on a central fixation point for 500 ms, followed by the presentation of the stimuli for 5,000 ms, until all stimuli were presented. Each object was accompanied by a scene name in which they were found. The subjects were instructed to remember each object for a later memory test. The study phase was followed by a five-minute visual distractor task. In the practice phase, half of the objects from half of the categories were again presented along with an equal number of novel objects. Subjects engaged in recognition practice by completing an old-new recognition task in response to each object. Each old object was practiced on two practice trials. The practice lures were objects drawn from the same categories as the practiced objects. The second phase was followed by another five-minute visual distractor task. The test phase employed the same old-new recognition task as the second phase, but included 36 old stimuli from the study phase (12 baseline, 12 practiced, and 12 related), as well as an equal number of novel test lures from the same categories. Hit rates from this test phase are presented in results figures by object type. The bottom panel illustrates the expected pattern of results in the presence and absence of recognition-induced forgetting. Maxcey et al. (2019) found no recognition-induced forgetting (illustrated on the right).

Schematically related categories fundamentally differ from basic-level categories because they consist of learned associative concepts composed of arbitrary stimuli related by accumulated experience rather than physical properties or inherent relationships (Lewis et al., 2015; Mirman et al., 2017; Zentall et al., 2014). For example, learning to categorize tractor and haystack as objects grouped under the schema *farm* occurs over time. Meanwhile, a bulldozer and a farm tractor can immediately be grouped based on physical resemblance, under the basic-level category of *tractor*. Indeed, recent work from our lab (see **Fig. 1**) has suggested that recognition-induced forgetting may not operate over temporally grouped objects (Maxcey, Glenn, & Stansberry, 2018) or pictures grouped by schema (Experiment 3, Maxcey et al., 2019).

Our inability to find recognition-induced forgetting for temporally (Maxcey et al., 2018) or schematically (Maxcey et al., 2019) grouped objects led us to conclude the recognition-induced forgetting does not operate over episodic memory (Maxcey et al., 2018). However, the following literature suggests that forgetting should operate over episodic memory (e.g., at the schematic level). First, prominent theories of forgetting that may account for recognition-induced forgetting are not constrained to semantic memory, including competition-based accounts (Jakab & Raaijmakers, 2009; Lewis-Peacock & Norman, 2014; Norman, Newman, & Detre, 2007; Raaijmakers & Jakab, 2013a, 2013b), inhibition accounts of forgetting (M. C. Anderson, 2003; Detre, Natarajan, Gershman, & Norman, 2013), and context accounts (Jonker, Seli, & MacLeod, 2013). Second, retrieval-induced forgetting, a seemingly closely related forgetting phenomenon, has been shown to operate over associative memories (Ciranni & Shimamura, 1999; Gómez-Ariza, Fernandez, & Bajo, 2012; Murayama, Miyatsu, Buchli, & Storm, 2014) and is generally thought to operate over episodic memory (M. C. Anderson, 2003; Levy & Anderson, 2002). Third, the potentially related cognitive phenomena of priming (Maxcey, McCann, & Stallkamp, under review), in which exposure to an object influences later processing of that object and related objects, is also not restricted to semantic associations (Ochsner, Chiu, & Schacter, 1994; Tulving & Schacter, 1990). Here we asked whether recognition-induced forgetting operates over memory representations categorized at the schematic level. This issue warrants systematic examination because our previous conclusion that recognition-induced forgetting does not operate over episodic memory (Maxcey et al., 2018) is at odds with the work described above. If the mechanisms underlying recognition-induced forgetting do not operate over episodic memory representations, then schematically grouped objects should not be susceptible to recognition-induced forgetting.

We modified the recognition-induced forgetting paradigm used by Maxcey et al. (2019) illustrated in **Figure 1** that presents objects grouped at the schematic level. In Maxcey et al. (2019), a text label above every study object explicitly informed the participant of the relevant schema (e.g., *kitchen* label above a refrigerator), serving as a shared recognition cue because the associated label always accompanied objects in each phase of the experiment (i.e., study, practice, or test). In Experiment 1 (**Fig. 2**), we strengthened schematic associations by temporally grouping related objects during the study phase (as in Maxcey et al., 2018) but with only one item practiced at a time (as in Maxcey et al., 2019) to prevent interference during the practice phase. In Experiments 2 (**Fig. 4**) and 3, we further strengthened schematic associations by replacing the text labels with compelling background scenes that visually depicted the schema, as if the objects were encountered in the schematically consistent location.

Experiment 1: Simultaneous Study Presentation with Label

To test whether objects categorized at the schematic level are susceptible to recognition-induced forgetting, we modified the standard recognition-induced forgetting paradigm. Objects were categorized at the schematic level (e.g., snake and cactus)

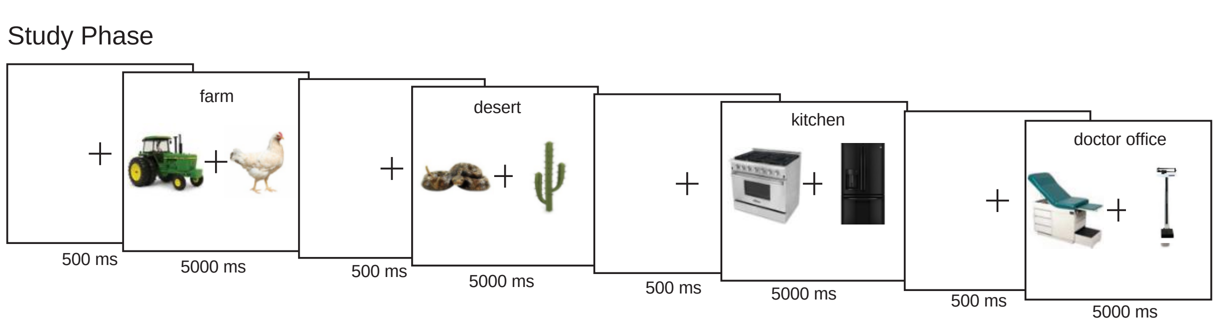

Figure 2. Sample of study phase from Experiment 1. Pairs of objects from the same schema were presented underneath a verbal label naming the associated schema.

instead of the basic level (e.g., two different cacti). To help participants relate objects at the intended schematic level, we presented a text label above objects denoting the relevant theme (e.g., *desert*). The recognition practice phase consisted of an old-new recognition task with sequential object presentation, rather than paired objects in previous studies (e.g., Maxcey et al., 2018; Maxcey & Woodman, 2014), to prevent practice interference[5]. Fourth, our sample size (n=48) was considerably larger than most recognition-induced forgetting studies. All of these changes should, in theory, elicit robust recognition-induced forgetting effects by inducing stronger associations for paired objects, reducing memory interference, and increasing statistical power.

We have previously found that recognition-induced forgetting is not observed when objects are categorized at the schematic level (Experiment 3, Maxcey et al., 2019). However, an alternative explanation is that schematic grouping produces inherently weaker object associations. To boost the strength of object associations, we temporally grouped objects, which has been shown to implicitly and automatically induce robust associations for attended objects (Fiser & Aslin, 2002; Kirkham, Slemmer, & Johnson, 2002; Olson & Chun, 2001; Turk-Browne, Jungé, & Scholl, 2005). In Experiment 1, every study trial consisted of two objects that shared the same schema and were studied at the same point in time, with their corresponding schema label displayed above.

Methods

[5]Maxcey et al. (2018) may have obscured evidence of recognition-induced forgetting due to practice interference where the recognition practice phase presented two objects to the left and right of fixation and participants were instructed to report which object was old (i.e., which object was previously presented in the study phase). However, this paired presentation could have interfered with memory for the studied object such that the temporally grouped study objects could have been overwritten by the temporally grouped practice objects.

Participants

Subjects were 48 Ohio State University undergraduates (mean age of 19.4 years, 28 female, 20 male) who completed the experiment in exchange for course credit.

Power analyses were performed using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the necessary sample size for recognition-induced forgetting studies, using the smallest effect size measured in the original recognition-induced forgetting paper and typical of literature on recognition-induced forgetting (d_z = 1.376, Experiment 1, Maxcey & Woodman, 2014). We estimated that a sample size of 12 subjects per experiment was necessary to observe recognition-induced forgetting effects with 99% power, given a .05 criterion of significance. We anticipated null results (i.e., no recognition-induced forgetting as measured by baseline minus related), so we chose a sample size of 48-50 subjects in each experiment to ensure adequate statistical power.

Stimuli

The experiment was programmed using E-Prime (Schneider, Eschman, & Zuccolotto, 2012). Subjects were seated approximately 80 cm from the monitor. Stimuli subtended approximately 4.6° of visual angle. Object categories in each experiment included 120 objects belonging to 12 categories (counterbalanced across subjects) drawn from a larger set of 24 categories[6].

Procedure

The general procedure of recognition-induced forgetting involves a study phase,

[6]Full stimulus set is on OSF:
https://osf.io/5s96y/?view_only=e1801f074078415f90e0e3e536b33b5f

a practice phase, and a test phase. Studied objects could belong to one of three object types: *practiced* objects, shown during the study and practice phase, *related* objects, the non-practiced objects of the pair from which the practiced objects belonged, and *baseline* objects, objects from the study phase pairs which were never practiced. During the practice and test phases, participants perform an old/new recognition judgment on whether they ever saw a given object before (we refer to new objects as *lures*). Recognition-induced forgetting is demonstrated if memory performance for related objects is poorer than baseline objects during the test phase. Our modification to this general procedure is illustrated in **Figure 2**. In the study phase, each trial consisted of two objects from the same schema simultaneously presented below the name of the relevant schematic category.

Each of the 24 trials lasted for 5 seconds, interleaved by a 500 ms fixation cross. Subjects were instructed to remember the objects for a later memory test. The study phase was followed by a five-minute delay in which the subjects engaged in an attentionally demanding visual task of searching for Waldo in *Where's Waldo* books.

Next, in the recognition practice phase, half of the objects from half of the studied categories (i.e., practiced objects) were sequentially presented below a schematic category label and subjects were instructed to make an old-new recognition judgment, indicating whether or not they had seen the object before. Practiced objects were practiced twice during this phase whereas each lure (drawn from the same category as the practiced objects) was only seen once. Hence, we needed twice as many unique lures as practiced objects, requiring 2 new objects from each of the 12 schematic categories included in the practice phase. The practice phase included 48 total trials (24 old, 24 new).

Another five-minute delay activity intervened the practiced phase and the test phase. The task during the test phase was the same as the practice phase. In this final old-new recognition task, 48 new objects were sequentially presented, evenly divided from each schematic category, along with all 48 old objects from the 24 studied pairs (12 related objects, 12 practiced objects, and 24 baseline objects) totaling 96 test phase trials.

Data Analysis

The primary dependent variable for recognition memory is hit rate across the three main object types (practiced, related, baseline). We report both the practice benefit (practice – baseline) as well as recognition-induced forgetting (baseline – related) even though the latter is the measurement of interest. In data figures the magnitude of the practice benefit is illustrated by the size of left bar (baseline is the x-axis) and the degree of recognition-induced forgetting is illustrated by the size of the right bar. To provide converging evidence for hit rate analyses, in the footnotes beneath the critical comparisons we also report the discrimination measure, *Pr*, which is Hit – False Alarm, and the associated bias measure, *Br*[7] (Feenan & Snodgrass, 1990). Pre-planned t-tests are accompanied by JZS Bayes factor to quantify support for the null or alternative hypothesis (Rouder, Speckman, Sun, Morey, & Iverson, 2009). JZS Bayes factor tells us the relative probability of the data under one model (the null hypothesis) compared to another model (the alternative hypothesis). For example, a $JZS_{ALT} = 3$ means the data are three times more probable under one model (the alternative

[7]When calculating *Br*, *Pr* values of 1 were changed to .99. For more information about *Pr,* see Ian Neath's useful website at https://memory.psych.mun.ca/models/recognition/index.shtml.

hypothesis) than under the other model (the null). Significant t-tests are accompanied by Cohen's d.

<u>Results & Discussion</u>

Replicating Maxcey et al. (2019), a repeated measures ANOVA comparing the means for baseline, related, and practiced objects ($F(2,94)=50.65$, $p<.001$, $\eta^2=.52$) indicated a reliable difference among the three object types (**Fig. 3**). Mean hit rates for practiced objects (.91, SD=.14) were significantly better than baseline objects (.68, SD=.21, $t(47)=8.33$, $p<.001$, $d=1.31$, $JZS_{ALT}=121{,}808{,}230$), demonstrating a practice effect (**Fig 3, left bar**). Consistent with our prediction that there would be no recognition-induced forgetting, related memories (.70, SD=.21) were not significantly different than baseline (.68, $t(47)=0.98$, $p=.331$, $JZS_{NULL}=6.05$, **Fig. 3, right bar**)[8]. The absence of recognition-induced forgetting here replicates the results of Maxcey et al. (2018) while controlling for practice interference.

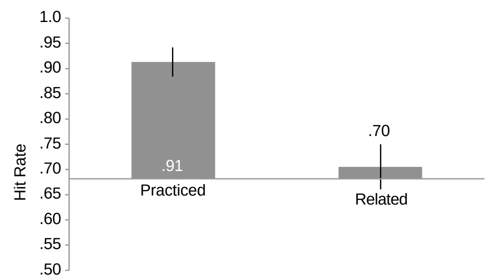

Figure 3. Hit rate for old objects in the test phase by object type fr om Experiment 1. In all data figures, the x-axis represents memory fo r baseline objects and error bars represent 95% confidence interva ls as described by Cousineau (Cousineau, 2005) with Morey' s correction applied (Morey, 2008).

Experiment 2: Simultaneous Study Presentation with Background Scene

One lingering question from Experiment 1 was whether participants were actually using the provided text labels to categorize related objects at the intended schematic level. To encourage participants to group objects as intended, in Experiment 2, study trials (**Figure 4**) consisted of two objects displayed on a schematically consistent

[8]Baseline *Pr* (.60, SD=.24) was statistically indistinguishable from related *Pr* (.63, SD=.24) ($t(47)=.982$, $p=.331$, $JZS_{NULL}=4.05$), with conservative biases for both baseline (*Br*=.21, SD=.17) and related (*Br*=.26, SD=.26).

background scene (replacing the text label). We also added a fourth phase, following the test phase, where memory for object pairs was tested to ensure that subjects had explicit knowledge of our intended schematic-level categories and successfully remembered the pairs.

Method

Participants

Subjects were 50 new Ohio State University undergraduates (mean age of 19.6 years, 19 female, 31 male) who completed the experiment in exchange for course credit.

Stimuli & Procedure

Stimuli and procedure were identical to Experiment 1 with the following exceptions. The experiment was programmed using HTML, CSS, and JavaScript. Each object subtended approximately 3.78 degrees of visual angle and each background scene subtended approximately 11.33 degrees of visual angle. The schematic-category label was replaced with a background scene consistent with the schematic category (see **Fig. 4**). A fourth phase was included where memory for object pairs was tested, consisting of two objects presented on the screen. Twelve old trials consisted of a randomly selected study trial and 12 new trials consisted of two objects, one old object drawn from a

Figure 4. An example of a study trial from Experiment 2. The studied objects were presented in front of a semantically consistent scene.

practiced category and one new object drawn from the same category as the object it replaced. The attentionally demanding distractor task consisted of five minutes of change-detection trials (e.g., Luck & Vogel, 1997). The experiment is available to try online[9].

Results & Discussion

Replicating Experiment 1 and Maxcey et al. (Experiment 3, 2019), a repeated measures ANOVA comparing the mean hit rates for baseline, related, and practiced objects ($F(2,98)=17.707$, $p<.001$, $\eta^2=.265$) indicated a reliable difference among the three object types (**Fig. 5**). Mean hit rates for practiced objects (.95, SD=.07) were significantly better than baseline objects (.87, SD=.13, $t(49)=4.649$, $p<.001$, $d=.70$, $JZS_{ALT}=805.85$), demonstrating a reliable practice benefit (**Fig. 5, left bar**). Again related memories (.85, SD=.14) were not significantly different than baseline (.87, $t(49)=1.135$, $p=.262$, $JZS_{NULL}=3.55$),[10] the absence of recognition-induced forgetting (**Fig. 5, right bar**). Memory for old pairs presented in the fourth phase averaged 94% accuracy (SD=.08), significantly better than chance ($t(49)=40.288$, $p<.001$, $d=5.70$, $JZS_{ALT}=5.25*10^{35}$), ruling out the possibility that recognition-induced forgetting was not observed simply because of a failure to remember the study phase pairs throughout the experiment. The absence of

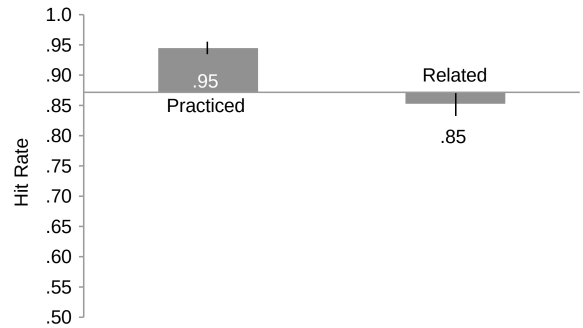

Figure 5. Mean hit rates by object type from test phase of Experiment 2.

[9] https://maxceylab.github.io/expts/compelling_scenes/5.html

[10] Baseline *Pr* (.83, SD=.15) was statistically indistinguishable from related *Pr* (.81, SD=.15) ($t(49)=1.135$, $p=.262$, $JZS_{NULL}=3.55$), and conservative biases for both baseline (*Br*=.33, SD=.38) and related (*Br*=.24, SD=.29).

recognition-induced forgetting here replicates the results of Experiment 1 and Maxcey et al. (2019) and suggests that insufficiently compelling temporal grouping cues cannot explain our lack of recognition-induced forgetting effects.

Experiment 3: Replicate Experiment 2 with Half the Exposure Duration at Study

The purpose of Experiment 2 was to encourage participants to notice the schematic relationship between the two objects. In Experiment 2, one may argue that recognition-induced forgetting was not observed due to ceiling effects, as baseline performance went up 19% from Experiment 1 (68%) to Experiment 2 (87%). The purpose of Experiment 3 was to lower performance using the same task as Experiment 2. To accomplish this, we cut the exposure duration of study phase objects in half in Experiment 3, from 5 seconds to 2.5 seconds. This enabled us to ask whether forgetting occurred for schematically related objects at a different range of memorability, when the task was harder and memory for the objects was lower.

Method

Participants

Subjects were 50 new Vanderbilt University undergraduates (mean age of 18.7 years, 43 female, 7 male) who completed the experiment in exchange for course credit.

Stimuli & Procedure

Stimuli and procedure were identical to Experiment 2 except that the exposure duration during the study phase was decreased from 5 seconds to 2.5 seconds. The experiment was approved by the Vanderbilt University Institutional Review Board. The experiment is available to try online[11].

[11] https://maxceylab.github.io/expts/compelling_scenes/2point5.html

Results & Discussion

A repeated measures ANOVA comparing the mean hit rates for baseline, related, and practiced objects ($F(2,98)=29.299$, $p<.001$, $\eta^2=.374$) indicated a reliable difference among the three object types (**Fig. 6**). Mean hit rates for practiced objects (.92, SD=.08) were significantly better than baseline objects (.81, SD=.18; $t(49)=5.310$, $p<.001$, $d=.80$, $JZS_{ALT}=6,585$), demonstrating a reliable practice effect (**Fig. 6, left bar**). Unlike previous experiments and contrary to our prediction, related memories (.77, SD=.18) were significantly lower than baseline (.81, $t(49)=2.571$, $p=.013$, $d=.27$, $JZS_{ALT}=2.95$)[12] resulting in reliable recognition-induced forgetting (**Fig. 6, right bar**). Recognition-induced forgetting here was likely due to the increased task difficulty relative to Experiment 2, as the methods were exactly the same between these two experiments except for study phase exposure duration. Indeed, it appears memory for schematically grouped pairs was more fragile in Experiment 3 relative to Experiment 2, measured by accuracy in the fourth phase in which memory for pairs was tested. Subjects averaged 87% accuracy (SD=.14) in Experiment 3, significantly lower than their performance in the fourth phase accuracy in Experiment 2 (94%, SD=.08; $t(49)=2.805$, $p=.007$, $d=.61$, $JZS_{ALT}=4.99$).

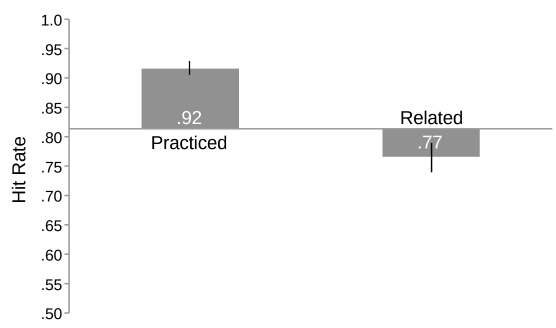

Figure 6. Mean hit rates by object type in the test phase of Experiment 3.

General Discussion

Here we found recognition-induced forgetting for perceptually distinct memory representations grouped by schema (Expt.

[12]Baseline *Pr* (.75, SD=.21) was reliably higher than related *Pr* (.71, SD=.21) ($t(49)=2.559$, $p=.014$, $JZS_{ALT}=2.88$), and conservative biases for both baseline (*Br*=.25, SD=.22) and related (*Br*=.24, SD=.27).

3), demonstrating that the mechanisms that underlie recognition-induced forgetting can operate over episodic memory. This is the first demonstration that this forgetting effect can be elicited by memories grouped at a representational level beyond the basic level employed in other studies of this effect (Maxcey, 2016; Maxcey & Bostic, 2015; Maxcey et al., 2016; Maxcey et al., 2019; Maxcey & Woodman, 2014; Rugo et al., 2017), contrary to our previous evidence that recognition-induced forgetting does not operate over higher-order groupings (Maxcey et al., 2018; Maxcey et al., 2019). When schematic relationships were relatively weak (Expt. 1) or strong (Expt. 2), recognition-induced forgetting was not observed. These results are consistent with models of forgetting that argue that the key determinant in forgetting is moderate activation (Detre et al., 2013; Lewis-Peacock & Norman, 2014; Norman et al., 2007).

We note that there is some ambiguity as to whether schematically related memories are episodic or semantic. On one hand, schematically related memories are created based on accumulated experience learning that certain objects often co-occur together, which fits the definition of episodic memory (i.e., information about temporally related events or relationships; Tulving, 1972). On the other hand, schematically related memories may also be semantically related (e.g., you are unlikely to find many objects in your kitchen that are semantically inconsistent with a kitchen schema). It is therefore still unclear whether recognition-induced forgetting can occur in the absence of *any* semantic relatedness. Indeed, this ambiguity has played a role in the argument that episodic memory and semantic memory may not be separate systems (McKoon, Ratcliff, & Dell, 1986). We argue that the results of experiment 3 demonstrate that recognition-induced forgetting can operate over episodic memory (in addition to semantic memory) because episodic association was one of three factors, in addition to moderate memory strength and semantic relatedness, shown important to elicit recognition-induced forgetting in perceptually distinct objects. Only by helping participants strengthen the episodic associations between objects via a compelling schema was the forgetting effect observed, demonstrating the involvement of episodic memory mechanisms in recognition-induced forgetting and more generally supporting the idea that episodic and semantic memory systems may not be independent.

What is the relationship between recognition- and retrieval-induced forgetting? Recognition-induced forgetting is similar to retrieval-induced forgetting (M. C. Anderson, Bjork, & Bjork, 1994). Their distinguishing feature is the task that induces forgetting: one is a recognition task and one a recall task. Both these tasks are retrieval tasks according to the classic model of memory in which the three stages of memory are encoding -> storage -> retrieval (Melton, 1963). Retrieval-induced forgetting has typically been interpreted to involve episodic retrieval (M. C. Anderson, 2003; Levy & Anderson, 2002), employing stimuli grouped by schema (Storm & Levy, 2012), operating over semantically unrelated associations (Ciranni & Shimamura, 1999; Gómez-Ariza et al., 2012), and even transcending languages (Levy, McVeigh, Marful, & Anderson, 2007).

Previous studies demonstrating recognition-induced forgetting have used hierarchically lower category levels of objects which may be confounded by perceptual similarity. This means that objects shared similar perceptual *and* semantic information (e.g., two feathers necessarily contain similar physical properties). Here, we demonstrated that when perceptual similarity for related objects was weakened, with measures taken to strengthen semantic similarity of schematic relationships, recognition-induced forgetting effects can be observed. These results inform models of forgetting by demonstrating that recognition-induced forgetting can operate over objects lacking perceptual similarities (see also Hong, Maxcey, & Leber, 2018; Hong, Scotti, Maxcey, & Leber, 2019, July 27), a finding that establishes increased generalizability of recognition-induced forgetting and suggests similar underlying mechanisms to retrieval-induced forgetting.

Figure Captions

Figure 1. Methods of Experiment 3 from Maxcey et al. (2019). In the study phase, subjects fixated on a central fixation point for 500 ms, followed by the presentation of the stimuli for 5,000 ms, until all stimuli were presented. Each object was accompanied by a scene name in which they were found. The subjects were instructed to remember each object for a later memory test. The study phase was followed by a five-minute visual distractor task. In the practice phase, half of the objects from half of the categories were again presented along with an equal number of novel objects. Subjects engaged in recognition practice by completing an old-new recognition task in response to each object. Each old object was practiced on two practice trials. The practice lures were objects drawn from the same categories as the practiced objects. The second phase was followed by another five-minute visual distractor task. The test phase employed the same old-new recognition task as the second phase, but included 36 old stimuli from the study phase (12 baseline, 12 practiced, and 12 related), as well as an equal number of novel test lures from the same categories. Hit rates from this test phase are presented in results figures by object type. The bottom panel illustrates the expected pattern of results in the presence and absence of recognition-induced forgetting. Maxcey et al. (2019) found no recognition-induced forgetting (illustrated on the right).

Figure 2. Sample of study phase from Experiment 1. Pairs of objects from the same schema were presented underneath a verbal label naming the associated schema.

Figure 3. Hit rate for old objects in the test phase by object type from Experiment 1. In all data figures, the x-axis represents memory for baseline objects and error bars represent 95% confidence intervals as described by Cousineau (2005) with Morey's correction applied (Morey, 2008).

Figure 4. An example of a study trial from Experiment 2. The studied objects were presented in front of a semantically consistent scene.

Figure 5. Mean hit rates by object type in the test phase of Experiment 2.

Figure 6. Mean hit rates by object type in the test phase of Experiment 3.

Open Practices Statement

The stimuli and data are available on Open Science Framework at https://osf.io/5s96y/?view_only=e1801f074078415f90e0e3e536b33b5f.

Experiment 2 is available to try online at https://maxceylab.github.io/expts/compelling_scenes/5.html

Experiment 3 is available to try online at https://maxceylab.github.io/expts/compelling_scenes/2point5.html

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Footnotes

[1]While the development of concepts and category learning are critical to interacting with the world (Sloutsky, 2010), they are beyond the scope of this work.

[2]See the General Discussion for a comparison between recognition- and retrieval-induced forgetting.

[3]The recognition-induced forgetting paradigm, by definition, presents additional novel pictures in the old-new recognition judgment task. Our lab has demonstrated that forgetting is not parametrically manipulated by set size, suggesting that forgetting is not due to retroactive interference but is indeed the result of recognition (Maxcey, 2016).

[4]In a previous study (Maxcey et al., 2019) using this level of grouping, we employed the term *superordinate* rather than *schematic*. The types of relationships we test here could also be referred to as *superordinate* at the very abstract level, or as *thematically* related if constrained to objects of different functional roles (Goldwater, Markman, Stilwell, 2011). Here for the sake of consistency and precision, we use the term *schematic* to describe the association among our stimuli.

[5]Maxcey et al. (2018) may have obscured evidence of recognition-induced forgetting due to practice interference where the recognition practice phase presented two objects to the left and right of fixation and participants were instructed to report which object was old (i.e., which object was previously presented in the study phase). However, this paired presentation could have interfered with memory for the studied object such that the temporally grouped study objects could have been overwritten by the temporally grouped practice objects.

[6]Full stimulus set is on OSF:
https://osf.io/5s96y/?view_only=e1801f074078415f90e0e3e536b33b5f

[7]When calculating *Br*, *Pr* values of 1 were changed to .99. For more information about *Pr,* see Ian Neath's useful website at https://memory.psych.mun.ca/models/recognition/index.shtml.

[8]Baseline *Pr* (.60, SD=.24) was statistically indistinguishable from related *Pr* (.63, SD=.24) ($t(47)$=.982, p=.331, JZS_{NULL}=4.05), with conservative biases for both baseline (*Br*=.21, SD=.17) and related (*Br*=.26, SD=.26).

[9]https://maxceylab.github.io/expts/compelling_scenes/5.html

[10]Baseline *Pr* (.83, SD=.15) was statistically indistinguishable from related *Pr* (.81, SD=.15) ($t(49)$=1.135, p=.262, JZS_{NULL}=3.55), and conservative biases for both baseline (*Br*=.33, SD=.38) and related (*Br*=.24, SD=.29).

[11]https://maxceylab.github.io/expts/compelling_scenes/2point5.html

[12]Baseline *Pr* (.75, SD=.21) was reliably higher than related *Pr* (.71, SD=.21) ($t(49)$=2.559, p=.014, JZS_{ALT}=2.88), and conservative biases for both baseline (*Br*=.25, SD=.22) and related (*Br*=.24, SD=.27).