9

HOW TO INDUCE THE FORGETTING OF PICTURES

Ashleigh M. Maxcey, Elizabeth Mancuso, Paul S. Scotti, Emily Spinelli, and Geoffrey F. Woodman

There are two findings in the visual long-term memory literature that appear to be logically inconsistent with each other. On the one hand, humans appear to be able to remember essentially a limitless amount of visual information (Standing, 1973). On the other hand, studies of false memory suggest that information can be easily forgotten, even when presented visually (Loftus & Palmer, 1974). How can both of these robust findings simultaneously exist? Work from our laboratories can help answer this question by showing that accessing an item in visual long-term memory can cause forgetting of other related exemplars (Maxcey & Woodman, 2014). Outside the laboratory, the occurrence of multiple exemplars from the same category happens all the time (e.g., apples at the grocery store, flowers in the garden, chairs in a classroom, or children on the playground). Thus, while visual memory for individual objects may be quite strong, accessing memory for an individual exemplar improves memory for the retrieved item and *induces* the forgetting of related memories stored near it in psychological space.

We have shown that this *induced forgetting* is ubiquitous. We have found induced forgetting in children aged 6–10 (Maxcey & Bostic, 2015), and older adults aged 65 and older (Maxcey et al., 2016), even though these populations show a reduced ability to learn new visual information relative to healthy young adults. Induced forgetting occurs for objects of expertise (Rugo et al., 2017; Spinelli et al., under review) and words (Maxcey et al., 2019). Induced forgetting occurs following recognition (Maxcey, 2016; Maxcey & Woodman, 2014) but also following restudy of exemplars (Maxcey, Janakiefski et al., 2019), and the correct rejection of completely novel exemplars (Fukuda et al., 2020). Induced forgetting appears to operate over schematically grouped objects (Scotti, Janakiefski, & Maxcey, 2020), rather than temporally grouped objects (Maxcey, Glenn, & Stansberry, 2018). Induced forgetting appears to be a result of probing memory using episodic memory tasks rather than semantic memory tasks (Maxcey, McCann, & Stallkamp, 2020). The boost in memory for retrieved items is separable from the forgetting effect (Maxcey et al.,

 DOI: 10.4324/9781003158134-10

in press) and is not due to shifts in decision-making thresholds (Megla, Woodman, & Maxcey, 2021). This forgetting effect is so robust that it occurs even when observers are informed about its presence and instructed to eliminate this forgetting (Maxcey, Dezso, Megla, & Schneider, 2019). Induced forgetting is more robust than directed forgetting, a popular method of inducing forgetting in the laboratory (Scotti & Maxcey, 2021). Thus, the empirical utility of induced forgetting is clear.

What is only beginning to come into focus through this work is the nature of the cognitive architecture that underlies it. In the present chapter we present novel findings that answer three questions: (1) Does induced forgetting operate over objects lacking semantic information? (2) Does induced forgetting operate over emotionally arousing stimuli? (3) Does induced forgetting depend on interference generated by objects from other categories? We end by discussing process models that can and cannot account for the present results, as well as the features of the phenomenon reviewed above.

General methods

In the novel experiments reported here, all subjects reported normal color vision, normal or corrected-to-normal visual acuity, and fluency in English. Informed consent to procedures approved by the Institutional Review Board was obtained at the outset. Sample sizes were motivated by an a priori power analysis. Additional details about each experiment can be found on their individual Open Science Framework (OSF) pages (links where each experiment is described).

All experiments used a variant of the following paradigm (Figure 9.1). Subjects began by viewing sequentially presented pictures for 5 seconds each, interleaved by a 500 ms fixation cross, until all pictures were presented during an initial study phase. Subjects were instructed to remember the visual details of the pictures for a later memory test. The pictures were presented in random order, drawn from a set comprised of multiple exemplars from each picture category (Figure 9.2).

In the practice phase, subjects were presented with a subset of pictures from the study phase (e.g., half of the pictures from half of the categories, Figure 9.2) as well as an equal number of novel pictures from the corresponding categories.[1] For example, if the object category is lamp, then trials presenting lamps will have a 50/50 old/new correct response distribution. The subject's task was to report whether each picture was old or new (i.e., an old-new recognition judgment task).

The design of the practice phase resulted in three picture types (Figure 9.2). *Practiced* pictures are studied during the study phase and practiced twice during the practice phase (i.e., presented three times total before the test phase). *Related* pictures are studied during the study phase, but are not practiced during the prac-

1 Typically, the induced forgetting paradigm presents additional novel pictures in the old-new recognition test phase at the end of the experiment. Our laboratory 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 seeing some of the pictures again (Maxcey, 2016).

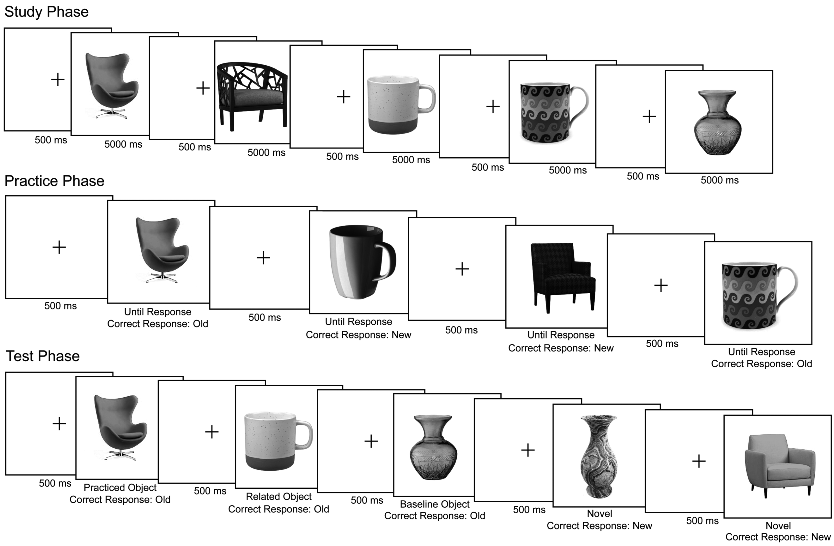

Figure 9.1 General procedure for inducing the forgetting of pictures. Subjects view a series of to-be-remembered photographs, they then recognize a subset of them or restudy them, with the session ending after a final memory test. Not shown, a five-minute visual distractor task (e.g., *Where's Waldo* or a change detection task) created a five-minute delay between each adjacent phase. In the test phase, induced forgetting is shown by worse memory for related objects relative to baseline objects. Neither related nor baseline objects were presented in the practice phase. The only difference between these two object types is that related objects belong to a category of objects (e.g., mugs) that had some practiced exemplars. (The term *related* refers to their relation to practiced objects.) It is the relationship between related objects and practiced objects that must underlie induced forgetting.

tice phase (i.e., presented once before the test phase). However, related pictures are drawn from categories of pictures that had some practiced pictures (e.g., butterflies were practiced, but not this particular butterfly). *Baseline* pictures are studied during the study phase, but are not practiced during the practice phase (i.e., presented once before the test phase). Baseline pictures differ from related pictures because baseline pictures are drawn from entire categories of pictures that were not practiced (e.g., none of the chairs were practiced).

In the final phase, the test phase, subjects completed another old-new recognition judgment task. Old baseline, related, and practiced pictures were randomly interleaved with an equal number of novel pictures from the same picture categories. Again, the pictures were presented in random order and were visible until response. Across subjects, pictures were counterbalanced across the picture types (practiced, related, and baseline).

Induced forgetting is present when memory for related objects is reliably worse than memory for baseline objects. All studies reported here showed the same pat-

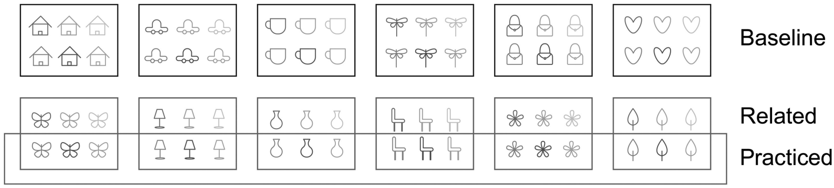

Figure 9.2 Illustration of the old object types tested in the final phase. Practicing a subset of the pictures during the practice phase creates these object types. During the practice phase, half of the objects from half of the categories are practiced (shown in red box). The remaining objects from the practiced categories are related objects. The objects from non-practiced categories are baseline objects. The signature of induced forgetting is worse memory for related objects than baseline objects, even though both objects were only seen once during the study phase. The only difference between these objects is that related objects are *related* to practiced objects. Experiments reported in this chapter may have differed in the overall number of categories and exemplars, but the same general concept behind the three object types applies to all experiments.

terns of results when we calculated hit rate and other indices of sensitivity from signal-detection theory (i.e., a', d', etc.). Pre-planned t-tests were accompanied by scaled JZS Bayes factor calculations to quantify the support for the null or alternative hypothesis (Rouder, Speckman, Sun, Morey, & Iverson, 2009).

Recognition-induced forgetting operates across networks of semantically, not perceptually, linked visual memory representations

One challenge to incorporating induced forgetting into models of memory is defining the underlying representational structure that gives rise to these effects. Because observers forget the objects that are categorically related to the practiced memories, perhaps an activation pulse spreads across our memories stored by category (e.g., all of the *dog* exemplars you have experienced) boosting the target memory and weakening the related memories, resulting in us forgetting the categorically related objects we saw.

Despite making strides toward modeling induced forgetting (Fukuda et al., 2020; Maxcey, Dezso et al., 2019; Maxcey et al., 2020), two possible category structures, semantic and perceptual, may define the relationship among visual memory representations. There are several reasons for this ambiguity. First, categories employed in these experiments share both perceptual and semantic features. For example, all butterflies have similar perceptual features (e.g., round wings, brightly colored), which may be driving their grouping, but they also share similar semantic relationships (e.g., nectar eating, flying insects). Second, while we found that semantic, not temporal, information was the grouping cue driving induced forgetting when we paired two pictures together (Maxcey et al., 2018), induced forgetting can operate over temporally grouped pictures under specific circumstances (Scotti et al., 2020). Given this, it is possible that forgetting is induced onto

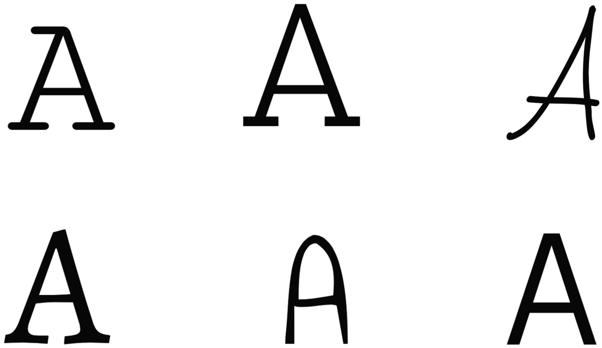

Figure 9.3 Sample stimuli from *Recognition-induced forgetting operates across networks of semantically, not perceptually, linked visual memory representations*. The category is "A" and the exemplars are comprised of the letter "A" in different fonts.

representations that are both semantically similar and perceptually similar. Third, we have shown that induced forgetting is a consequence of episodic memory tasks that may have implicitly emphasized perceptual features (e.g., continued studying of a list or an old-new recognition judgment task), but not a semantic memory task (e.g., when making size judgments, Maxcey et al., 2020). It is possible that forgetting was not observed when subjects made a semantic judgment about each stimulus because the task implicitly emphasized non-perceptual features. While it has been shown that induced forgetting can occur for objects that are semantically related but not perceptually related (Scotti et al., 2020), it is unknown whether induced forgetting can occur for objects that are semantically unrelated but perceptually related.

Here we tested the importance of semantic and perceptual similarity to induced forgetting by employing a special stimulus set. These were stimuli that participants could categorize without instruction using perceptual information, but also lack semantic features. To this end, we employed letters as the category (e.g., one category was "A", Figure 9.3) and different fonts for the exemplars (e.g., the "A" category consisted of "A" in a variety of fonts). Letters are ideally suited to use in an induced-forgetting paradigm because letters are a category of stimuli that are viewed daily. Participants are able to categorize them quickly and efficiently without instruction (e.g., As belong to the same group) just like other stimuli employed in this paradigm (e.g., mugs belong to the same group). Letters are also ideal for this particular experiment because we sought a stimulus set with shared perceptual information, but little to no shared semantic information, because letters have little to no semantic content themselves (e.g., there is arguably no such thing as the H-ness of an h, with some exemplars having more h-ness than others).[2]

2 Our approach assumes that letters have minimal semantic grouping. One may argue that some letters have significant semantic information, such as "A" is frequently associated with *apple*, or

This can be demonstrated in a number of ways. First, letters have linguistic affordances where a letter is used to build up to a word, but the letter alone does not carry semantic information. This is unlike other natural categories, such as vases, which carry semantic information on their own. Second, the category of letters behaves unlike other natural categories. For letters, category membership is discrete and not graded as it is with other natural categories. Letters have sharp boundaries (e.g., "A" versus "O") whereas natural categories have graded boundaries (Taylor, 2001), where some members are more representative of category membership (e.g., a blue jay is a better example of a bird compared to a turkey).

Hypotheses and predictions

Here we tested two competing hypotheses focused on the role of semantic information in induced forgetting. According to the *semantic-grouping hypothesis*, semantic relationships between category members are necessary for induced forgetting to spread between members. If semantic information is required for induced forgetting, then letters will not be susceptible to forgetting because letters have little to no semantic information themselves. On the other hand, according to the *perceptual-grouping hypothesis*, perceptual similarity may define relationships between category members for induced forgetting to spread between memory representations. If perceptual information is sufficient for induced forgetting, then letters will be susceptible to forgetting despite the fact that they have little to no semantic information.

Method

Details about this experiment are on OSF[3] and can be run online.[4]

The critical distinction between the present experiment and previous induced forgetting experiments is that the categories were specific letters (e.g., the letter "G" was one category) and the exemplars within that category are the fonts (the entire stimulus set is on OSF).

Results

We entered the hit rates into a repeated measures ANOVA that yielded a significant effect of object type (i.e., practiced, related, and baseline, $F(2,94) = 36.954$,

perhaps a letter is significant because it is the initial of one's own name (e.g., "Anne"). However, here we randomly select ten letter categories for each subject, decreasing the chances of significant semantic relationship with a letter category for a given subject. In addition, listing words that start with a letter is arguably weak semantic information, given that semantic information is defined by a relationship in meaning (e.g., apple, Anne, and alligator have nothing in common other than the letter "A").

3 https://osf.io/wtyp8/

4 https://maxceylab.github.io/expts/letters/GeneralProcedure_Lab.html

$p < .001$, $\eta_p^2 = .440$). However, the key measure of forgetting, the difference between related letters (.57) and baseline letters (.59), was not significant, indicating the absence of induced forgetting, $t(47) = .655$, $p = .516$, $JZS_{NULL} = 5.62$[5]. Memory for practiced letters was about 20% higher than related and baseline (.76), ruling out the possibility that performance was low overall, preventing any room for forgetting. These results are consistent with the semantic-grouping hypothesis in which semantic information is necessary for induced forgetting, and inconsistent with the perceptual-grouping hypothesis, according to which letters should show forgetting because they share basic perceptual features.

Discussion

Here we asked whether semantic or perceptual information forms the structure across which induced forgetting spreads. Letters are well-known objects that subjects implicitly group together based on shared perceptual features (e.g., all "A" exemplars are defined by two oblique lines that intersect at the top, transected by one horizontal line), but lack meaning in and of themselves. Consistent with the semantic-grouping hypothesis, we found that letters were immune to induced forgetting.

One may argue that letters may contain semantic information across capital and lower-case letters where perceptual similarity may be quite low (e.g., "a" and "A") but we nevertheless learn they belong to the same category. The same may hold true across various fonts, where some perceptual modifications are non-diagnostic (e.g., the top of the "A" may be pointed or rounded) while others are diagnostic (e.g., the bisecting horizontal line of the "A"). These arguments both predict induced forgetting when using letters, contrary to the present results. Nevertheless, future work should employ non-semantic stimuli that have no potential for semantic grouping.

One may wonder whether the semantic grouping and perceptual grouping hypotheses are mutually exclusive, or if semantic and perceptual information may be flexibly used under different circumstances, leading to different grouping cues underlying induced forgetting. Here we show that this is not the case because when perceptual information must be used to distinguish stimuli, induced forgetting does not occur.

Interestingly, even according to the semantic-grouping hypothesis it should be possible to observe induced forgetting with letter stimuli. Specifically, an observer could impose a top-down semantic structure over a group of items that are only similar along perceptual features (Craik & Lockhart, 1972). For example, we predict that if you train subjects to impose a semantic structure on these letters of different fonts (associate Arial with grant money, Comic Sans with pre-school, etc.), then forgetting of neighboring items might be induced.

Here we establish that the category structure defining the space across which induced forgetting operates is semantic, not perceptual. These findings are consist-

5 The absence of induced forgetting was replicated using AUC, $t(47) = .655$, $p = .516$, $JZS_{NULL} = 5.21$.

ent with other spreading activation phenomena in the memory literature, such as the fan effect and priming (J.R. Anderson, 1974; McNamara, 2005). Priming is a particularly relevant spreading-activation phenomenon because there are both semantic and perceptual flavors of priming (Jacoby & Dallas, 1981). However, induced forgetting is unlike priming in that induced forgetting only has semantic induction; perceptually induced categories are not sufficient to support the spread of forgetting across its category members. Here we show that accessing a visual memory representation causes a pulse of activity to shoot through the network of semantic memory representations, traveling only on semantic tracks, boosting the targeted memory and suppressing the surrounding competing memories.

Forgetting negative visual memories occurs after activating related negative memories

Brett Kavanaugh was nominated to become a United States Supreme Court Justice in 2018. During the hearings in the U.S. Senate, Kavanaugh was accused of sexual assault by Dr. Christine Blasey Ford. The assault allegedly took place while the two were in high school, an event that occurred 36 years prior. In Dr. Ford's testimony, she reported that the laughter of her alleged assaulters was "indelible in the hippocampus", referring to her perception of having a veridical and strong memory of the traumatic event (Ford, 2018). The described event represents a conflict between two opposing features of human memory. On one hand, emotional memories are better remembered than non-emotional memories (Hamann, 2001; Phelps, 2004). On the other hand, memories are malleable and imperfect (Loftus & Palmer, 1974). Further complicating this relationship, emotion and memory are subserved by functionally interacting brain regions (Yonelinas & Ritchey, 2015). Here we ask how emotional valence modulates forgetting using the laboratory paradigm we introduced above.

Although the induction of forgetting could be adaptive and even desirable, as in forgetting disturbing events, it can be harmful in other cases. In a real-world example of identifying the face of the gunman from a bank robbery in a lineup, this accessing of an existing memory should induce the forgetting of the face of the driver of the getaway car. However, it is unclear whether emotional arousal ameliorates induced forgetting, enabling accurate eyewitness testimony. Here we pit these opposing memory modifiers (i.e., emotional arousal and induced forgetting) against one another by asking whether emotionally arousing memories are susceptible to induced forgetting. To this end, we presented subjects with neutral, positive, and negative emotionally arousing pictures. We asked whether induced forgetting of the arousing pictures was possible.

Hypotheses and predictions

There are reasons to believe that induced forgetting does not operate over emotionally arousing pictures. First, emotional arousal tends to boost memory (Yonelinas & Ritchey, 2015), translating a fragile memory into one that is resistant to forgetting.[6] Second, in studies of the induced forgetting of words (M.C. Anderson et al., 1994), unpleasant and pleasurable word stimuli were forgotten less often than neutral words, suggesting that emotionally arousing stimuli were not subject to induced forgetting (Dehli & Brennen, 2009). Third, the ability to recall negative memories is associated with reductions in induced forgetting (Storm & Jobe, 2012), pointing to a potential link between reduced forgetting in the face of remembering negatively arousing stimuli. In summary, all these findings suggest that an emotionally charged stimulus may not be easily forgotten.

On the other hand, there are also reasons to believe that we can induce the forgetting of emotionally arousing pictures. First, induced forgetting is a robust and reliable effect (Maxcey, 2016; Maxcey & Bostic, 2015; Maxcey et al., 2016; Maxcey et al., 2018; Maxcey, Janakiefski et al., 2019; Maxcey & Woodman, 2014), robust enough to persist despite knowledge of the forgetting effect (Maxcey, Dezso et al., 2019) and occurring after mere exposure to pictures held in memory (Maxcey, Janakiefski et al., 2019). The cognitive impenetrability of induced forgetting is uncommon among popular memory paradigms in which the subject's naiveté is critical to demonstrating forgetting (Bjork, 1972; Bjork et al., 1968; Brown, 1954; Epstein, 1972; Loftus & Palmer, 1974; MacLeod, 2012; Muther, 1965), and suggests emotionally arousing stimuli may not be immune to its effect. Second, induced forgetting (Barber & Mather, 2012; Barnier et al., 2004; Kuhbandner et al., 2009), and socially shared induced forgetting (the forgetting of unmentioned but related information in conversation, Coman et al., 2009) have been demonstrated with arousing memories and broad categories of autobiographical memories (Hauer & Wessel, 2006; Stone et al., 2013), but with some caveats such as the sex of the speaker (Barber & Mather, 2012), the emotional intensity of the stimulus (Kuhbandner et al., 2009), and the mood of the subject (Bauml & Kuhbandner, 2007).

Methods

The experiment followed the general paradigm (see Figure 9.1) with the following exceptions. The stimuli were pictures drawn from the International Affective Picture System (Lang, 2005), supplemented with pictures from Google Images (images.google.com) (see Figure 9.4 and OSF[7]). In an emotional rating experiment, subjects identified the emotion depicted in images as positive, negative, or neutral. Subjects then rated the emotional intensity of the items on a scale of 0–3 where 0 = not emotionally intense at all, 1 = low emotional intensity, 2 = medium emotional intensity, and 3 = extremely emotionally intense. The rating experiment used laypeople's terms for emotional information, allowing emotional arousal and

6 We acknowledge that affective valence and arousal have been theoretically dissociated in literature on memory. However, this distinction was not made in the literature immediately relevant to the present study and therefore we do not distinguish them here.

7 Stimuli and additional methodological details here: https://osf.io/nhdsb/

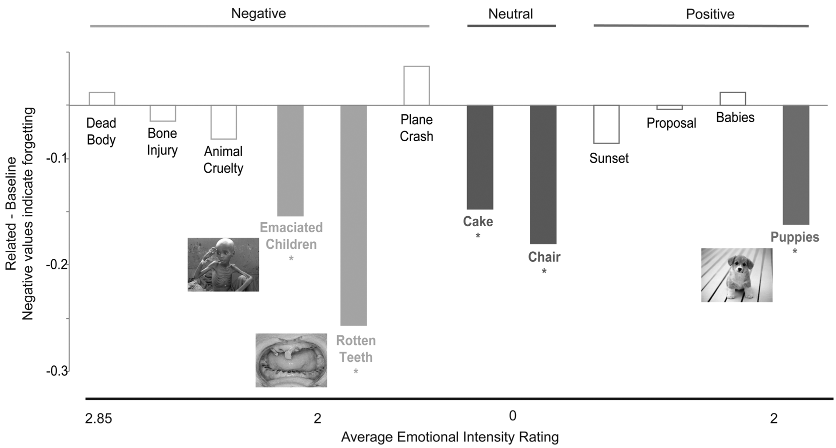

Figure 9.4 Sample stimuli and results from *Forgetting negative visual memories occurs after activating related negative memories*. Induced forgetting operated over moderately negative memories (i.e., emaciated children and rotten teeth), neutral memories (i.e., chair and cake), and extremely positive memories (i.e., puppies).

emotional intensity to be interchangeable and valence to refer to neutral, positive, or negative. For simplicity, we continue this nomenclature throughout the study.

Results

Figure 9.4 shows the results collapsed across two experiments using different stimuli for simplicity and efficiency. Induced forgetting operated over the most positively arousing images (e.g., puppies), neutral images (i.e., cake, chair), and the moderately (but not extremely) negative images (e.g., emaciated children and rotten teeth), demonstrating that it is possible to induce the forgetting of emotionally charged stimuli.

Discussion

Here we pitted two potentially opposing memory modifiers against one another: Emotional arousal and induced forgetting. We found that extremely positive, neutral, and moderately negative memories were susceptible to forgetting. This evidence that the mechanisms underlying induced forgetting can trump emotion is consistent with evidence that induced forgetting is an extremely robust effect (Maxcey, Dezso et al., 2019; Maxcey, Janakiefski et al., 2019). These results also serve to further dissociate induced forgetting of visual stimuli from induced forgetting of verbal materials (M.C. Anderson et al., 1994), which is ameliorated by the use of negatively arousing words except under special circumstances (e.g., Barber & Mather, 2012; Dehli & Brennen, 2009; Kuhbandner et al., 2009). Future work should examine whether intrinsic memorability (Bainbridge, 2020) plays a role in stimuli across the emotional intensity scale.

Note that induced forgetting of negative objects follows an inverted-U-shaped function in which only the pictures rated in the middle of the emotional arousal scale were forgotten. This pattern of forgetting moderately activated memories appears on the surface to be consistent with a theoretical view that the memories we forget are those with medium levels of activation (Detre et al., 2013; Lewis-Peacock & Norman, 2014; Megla & Woodman, under review; Norman et al., 2007). The present findings also suggest that extremely negatively charged memories are difficult to forget. Memories such as those described by Dr. Ford may indeed be more robust than other memories (e.g., Barber & Mather, 2012; Kuhbandner et al., 2009), carrying implications for real-world scenarios such as eyewitness testimony and clinical settings (Bell et al., 2018; Ford, 2018).

Induced forgetting is a within-category forgetting effect

Induced forgetting appears to be caused by any task that asks subjects to remember multiple exemplars of a semantic category, with multiple presentations of some of the exemplars. However, does the induction of forgetting really end at the middle phase of the paradigm, or might testing memory itself result in forgetting that constantly accumulates? Previous work may have missed these dynamics of induced forgetting due to averaging across the entire test phase. For example, it is possible that the magnitude of forgetting rapidly increases across the test phase. This is plausible because many more objects and object categories are presented at test than during the practice phase. At the extreme, it is possible that if we could measure the magnitude of forgetting at one point in time, that we would see little forgetting immediately after practice, with the lion's share of the effect accumulating during the test phase itself.

Hypotheses and predictions

We distinguished between competing hypotheses by controlling the number of intervening objects from other categories at test. Unbeknownst to the subjects, we divided the test phase into quarters. All exemplars from specific object categories were assigned either to be isolated to an individual quarter (i.e., a quartered category) or distributed across all quarters (i.e., a non-quartered category). This manipulation allowed us to measure potential differences in the magnitude of forgetting as a function of encountering other-category items.

This experiment can also be viewed as testing the effects of output interference, which is the reduction in memory performance with each individual memory test event (M.C. Anderson et al., 1994). If output interference at test plays a role in induced forgetting, serving to weaken memory for related objects (compounding the forgetting caused in the practice phase) then induced forgetting will be greater for categories that were spread across the entire test phase than categories that were isolated to the same quarter. This is because output interference would cause forgetting to increase as a function of the number of encountered other-category objects throughout the test phase, differentially impacting related objects

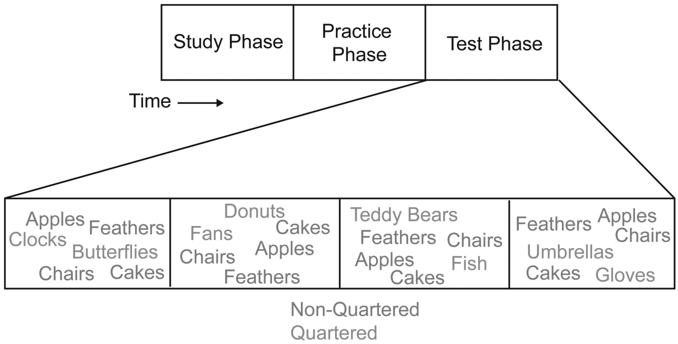

Figure 9.5 Illustration of the design used in *Induced forgetting is a within-category forgetting effect*. The test phase was divided into quarters, with two categories isolated to each quarter (blue) and the remaining four categories randomly distributed across all four quarters (green).

that are in a state more prone to forgetting. If induced forgetting is due to suppression during the practice phase, and not compounded by output interference at test, induced forgetting will be equivalent for categories isolated to quarters and categories spread across the test phase.

Methods

The stimuli were everyday objects available on OSF[8] and can be run online.[9]

The experiment was identical to the typical induced-forgetting paradigm described at the outset except as noted next. The unique aspect of this design was the serial ordering of objects in the test phase (Figure 9.5). The quartered categories have all of their exemplars (old and new) tested within that quarter of the test phase. The non-quartered categories were spread across the entire test phase, occurring equally often in each quarter.

Results

We first confirmed that induced forgetting occurred for both non-quartered categories and quartered categories. Induced forgetting was reliable for both non-quartered categories (hit rate: baseline (.62) – related (.56), $t(95) = 2.41$, $p = .0178$, $JZS_{ALT} = 1.75$, d': baseline (1.42) – related (1.17), $t(95) = 2.60$, $p < .001$, $JZS_{ALT} = 2.71$) and the categories isolated to a quarter of the test phase (hit rate: baseline (.63) – related (.56), $t(95) = 4.02$, $p < .001$, $JZS_{ALT} = 162$, d': baseline (1.43) – related (1.18), $t(95) = 4.25$, $p < .001$, $JZS_{ALT} = 356$).

8 https://osf.io/659kc/

9 https://maxceylab.github.io/expts/quarters/GeneralProcedure_Lab.html

Recall that the critical question is whether induced forgetting is greater for non-quartered object categories, due to the interference of encountering additional objects throughout the test phase. The magnitude of induced forgetting from non-quartered categories did not differ from the magnitude of induced forgetting from quartered categories (hit rate: t(95) = .373, p = .7100, d = .0381, JZS_{NULL} = 8.28, d': t(95) = 0.042, p = .9666, d = .0043, JZS_{NULL} = 8.85). These results are consistent with the idea that induced forgetting is driven by competitive interactions during the practice phase and not the accumulation of interference across the test phase as subjects encounter objects from other categories. Further, if the accumulation of interference across the test phase impacted induced forgetting, then the magnitude of forgetting would change over the course of the test phase. However, there is no reliable difference in the magnitude of induced forgetting from the first quarter to the last quarter (t(95) = .866, p = .389, JZS_{NULL} = 6.16).

Discussion

A commonly studied contributor to forgetting is interference (Roediger & Schmidt, 1980; Tulving & Arbuckle, 1963; Tulving & Arbuckle, 1966). Output interference refers to the concept that the odds of forgetting an item increase linearly as a function of its serial position in a list of items being tested (M.C. Anderson et al., 1994). Although output interference could not explain why induced forgetting operates over categories of objects, it could contribute to this forgetting effect. For example, even if interference impacts each object in the test phase equally, because related objects arrive at the test phase more fragile than baseline and practiced objects, they may be more susceptible to interference, much like a cracked plate is easier to break than one without a crack. If output interference worsens forgetting across the test phase, then induced forgetting may not be as robust of a forgetting effect as previously believed. Contrary to the idea that the induction of forgetting may be a progressive process across experimental phases and episodes of our lives, according to which interference across the test phase plays an additional role in inducing forgetting, here we showed that induced forgetting was driven by competition between representations during the practice phase.

Given the present evidence that forgetting was driven by the practice phase of the experiment and relatively stable thereafter, it may seem logical to conclude that the task context drives forgetting in these paradigms. For example, perhaps subjects mistakenly retrieve events from the practice phase at test, failing to remember what was learned during the study phase of the experiment. As we will describe further below, this does not seem to be a problem of mistaken source retrieval, meaning that contextual reinstatement models of memory struggle to explain the effects we have observed in this chapter.

Process models that cannot account for these effects

Encoding phase explanations

It is useful to work through several theoretical perspectives that cannot account for the patterns of forgetting we just described. First, it is natural to hypothesize that differences in the encoding of the objects may govern which images are forgotten and which are remembered. For example, if subjects blinked their eyes each time they saw one of the related objects, this could explain why subjects' memories of those objects are worse than the baseline objects. Although this seems possible, it is important to realize that the roles of the different pictures as practiced, related, and baseline are determined by what happens in the next phase of the experiment when some of the exemplars are shown again. This means that for an encoding difference to underlie this forgetting effect, subjects would also need to be able to see into the future to know which representations to ignore at encoding. Thus, differences in encoding clearly cannot account for the pattern of effects observed in these visual memory experiments.

Is it possible that selective rehearsal underlies the effects we have described in this chapter? That is, a classic explanation in the memory literature is that people remember certain items better because they rehearse these representations for longer periods of time during encoding (Glanzer & Cunitz, 1966). For example, if subjects performed elaborative rehearsal of the practiced and baseline objects, but not the related objects, then this could account for the pattern of performance on memory tests. However, this explanation would again require the subjects to anticipate which objects were going to be practiced in the future. Thus, it appears that logic rules out encoding as the locus of these induced forgetting effects.

Practice phase explanations

The forgetting of visual images is similar to the analogous forgetting phenomenon studied with linguistic memoranda, known as *retrieval-induced forgetting* (M.C. Anderson et al., 1994). In retrieval-induced forgetting tasks, forgetting is not observed when subjects restudy certain words (M.C. Anderson, 2003; Storm & Levy, 2012). Instead, it appears that people need to retrieve the memory, with this cognitive process inherently involving the suppression of the most potent distractors (i.e., the categorically related objects in memory) to pull out the word of interest. This literature has shown that when people perform stem completion (e.g., subjects are shown FRUIT:Ap____ and must report that "Apple" is the word from a previous study phase that completes the stem) this act of retrieval seems to be sufficient to forget words from the same category (e.g., retrieving apple induces the forgetting of banana).

It is important to note that this same theoretical proposal does not appear to account for the forgetting of visual representations. Unlike the conditions necessary to forget words, the forgetting of visual representations occurs even when people simply restudy certain exemplars (as described above and in Maxcey, Janakiefski et al., 2019). This means that the cognitive process of retrieval cannot be causing the forgetting of visual representations alone. It might be possible that retrieval is acting in these visual memory paradigms, but one would need to propose that the retrieval of previous matching exemplars is automatic. Perhaps any time a picture of an object is seen, we retrieve the matching exemplars that we have previously seen. With this kind of additional assumption, it is possible that the retrieval of a visual representation could be causing forgetting even as observers restudy certain pictures.

Is it plausible that every object we view automatically triggers the retrieval of previous instances of that object? Several theories propose that just this kind of automatic retrieval exists. Specifically, Logan (1988) proposed a learning model of automaticity in which seeing an object automatically causes the retrieval of previous instances of that object. This proposal is completely consistent with the idea that retrieval is obligatory. However, this is not a universal view. Evidence for early selection suggests that when people do not attend to an object, we fail to recognize it because the input is not matched with existing memory representations (Vogel et al., 2005). Due to these conflicting views, it is not clear whether the retrieval explanation of forgetting that was developed to account for the forgetting of words can be extended to account for the forgetting of visual objects.

Test phase explanations

Is it possible that the evidence for forgetting is due to the operation of cognitive mechanisms during the final memory test? Under such a proposal, the fidelity of the memory representations for the practiced, related, and baseline objects is approximately equal following the practice or restudy phase of the paradigm. The difference in recognition performance must then be due to decisions that are made when the test items appear. For example, it is possible that people know that they saw many of one type of object (i.e., the practiced and related objects of a single category). It is possible that they decide that since they saw many of these objects, they are going to require a stronger memory of that object to respond "old", indicating that they had previously seen this object. What we are describing here is a process model in which people first identify the category, and then decide about the exemplars after changing their decision threshold. Such an explanation might explain why memory for related items appears worse than that of baseline items.

Although a late-stage, decision-making locus of induced forgetting seems possible, findings from the literature suggest this is not the case. Several studies have examined behavior to address the possibility that this effect attributed to forgetting is actually due to changes in how people make decisions (Maxcey, 2016; Maxcey & Woodman, 2014). If people were shifting their criterion, then we should see that not only hits change depending on the category of objects tested, but also the false alarms should change. However, research has consistently shown that the increase in hits does not come at the expense of increasing false alarms. In addition, a recent study shows that electrical brain activity indexing the strength of the stored memories has shown that the brain's response to categorically related objects is weaker than that elicited by baseline objects (Megla et al., 2021). Thus, neither people's behavioral performance nor brain activity appears consistent with a late-stage, signal-detection theory explanation of the findings.

Another flavor of model that would seem to be able to account for the present results are contextual reinstatement models (Jonker et al., 2013; Polyn et al., 2009; Sederberg et al., 2008). These models propose that people are poor at discriminating the related objects from the practiced category because when they see one of those objects, they retrieve the practice context instead of the initial study context, driving incorrect responses. Although these are powerful models of human memory, there is not empirical support for the idea that context reinstatement drives these induced forgetting effects.

Contrary to predictions of contextual reinstatement models, researchers have shown that induced forgetting survives extremely robust shifts in external context (Maxcey et al., in press). When subjects are placed in separate testing rooms for the study and practice phases of an induced-forgetting experiment, contextual reinstatement models predict that returning to the study phase room for the final memory test will eliminate forgetting because people will retrieve the phase in which they learned those objects. Contrary to this prediction, returning to the study phase room for the final memory test does not eliminate forgetting. The type of contextual manipulation that does eliminate forgetting is time. This study showed that interfering with subjects' ability to mentally time travel by delaying the test phase 24 hours eliminated induced forgetting by disrupting internal shifts of context.

A viable process model of induced forgetting

Here we summarize the essential elements of induced forgetting that must be demonstrated in a process model of this effect. First, the practice effect (i.e., the boost in memory for practiced items) must be independent from the forgetting effect (Maxcey & Bostic, 2015; Maxcey et al., 2016). Second, the forgetting effect must dissipate over time, leaving the practice effect unaffected or even slightly boosted (Maxcey et al., in press). Third, the activation pulse that induces forgetting spreads across category space (Maxcey & Woodman, 2014). Fourth, the forgetting effect is caused by an episodic memory task (Maxcey et al., 2020). Here we describe a process model that we believe can account for these findings (Figure 9.6) (Maxcey et al., in press).

When an item is presented to observers in the test phase, the following sequence of operations unfolds (Figure 9.6, left). First, participants recognize the object as a member of a semantic category (e.g., a chair). This activates the exemplar in its semantic category in memory (i.e., a chair), but also spreads to neighboring representations through lateral connections, causing category-wide activation. The strength of the exemplar's activation increases with each additional presentation of that object, boosting the strength of that practiced memory. Next, memory retrieval mechanisms narrow in on the episode-relevant representations, locating elevated gradients in category space (Nosofsky, 2011). Activation in episodic memory spreads from the practiced item to representations of the rich context in which they were experienced, including the related objects. Bidirectional episode-relevant context activation results in a boost to the practiced items and suppression of the related objects. Finally, participants make button press responses based on the magnitude of this combined semantic and episodic activation.

Critically, the model illustrates how activation in episodic memory and semantic memory both play a role in forgetting and are required to account for all the essential elements outlined above. Specifically, the activation gradients occur over

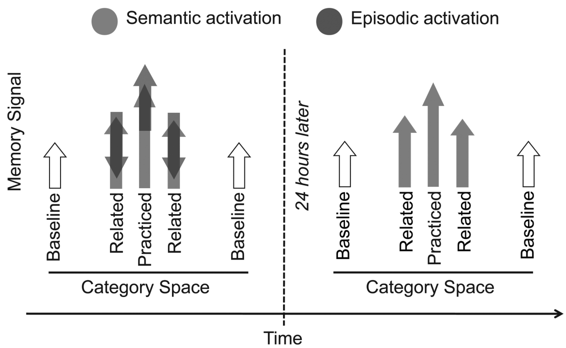

Figure 9.6 Proposed process model of induced forgetting. The left side represents induced forgetting when the practice and test phases occur closely coupled in time. The right side shows the diminished role of episodic grouping that happens after 24 hours (see also Maxcey et al., in press). Fun fact: We call this model the *Christmas tree model* because of the general shape it takes on and the festive colors we spontaneously used to draw it on our white board over winter break during the COVID-19 pandemic.

semantic memory but, over time, the episodic experience of seeing any given object becomes blurry, as previous temporal context becomes harder to access with more interference (Underwood, 1957). This means that over time the episodic association between the objects in a category is gone (Figure 9.6, right), eliminating the suppression that led to the forgetting of related objects. The activated semantic memory traces outlast the dissipation of episodic associations, allowing participants to complete the recognition task without the accompanying forgetting. This model can even account for a slightly increased practice effect after 24 hours, if one assumes lateral inhibition was operating over episodic memory associations.

The ideas presented in our cartoon model are generally consistent with a range of specific memory models, and there are many aspects that are yet to be discovered. What are the brain structures that maintain these different representations of the visual objects we encounter? Are inhibitory interneurons the source of the lateral inhibition that drives down competitors? What is the upside of having our memories compete so vigorously? As we describe next, the work on this induced forgetting phenomenon is just beginning.

Conclusion

One of the characteristics of visual long-term memory storage that makes it special is that it appears to be limitless. In comparison to human attention, working memory, decision-making, and response selection, all of which show extreme capacity limitations, visual long-term memory appears to show no cost of storing more and more information (J.R. Anderson, 2009). However, this conclusion may not be completely true. The research we reviewed here shows that the more of one type of object that we try to store, the harder it is to store each new one.

The induced forgetting phenomenon that we discussed here will obviously impact our ability to interact with the world in ways that are not yet understood. How does someone become an expert at discriminating exemplars of a category without suffering extreme interference and forgetting? This would seem to make it impossible to become a bird or a car expert, yet evidence for such visual expertise abounds (Rugo et al., 2017; Spinelli et al., under review). How does the rich perceptual experience of viewing a scene change how the isolated objects are stored? In the experiments that we reviewed and presented here, almost all of the objects were presented alone, with a couple presenting multiple objects or a more complex picture (including emotional content) (Scotti et al., 2020). It is possible that the structure of scenes makes objects more difficult to forget, like a visual analog of the word superiority effect in which more semantically rich stimuli are easier to process (McClelland & Rumelhart, 1981), not harder as we might intuit. Thus, although our chapter presented a number of new findings and reviews a large body of existing evidence pointing to interactions between visual long-term memory representations, much work remains to be done to integrate the induced forgetting effects into the broader literatures of visual cognition, cognitive psychology, and neuroscience.

Author contributions

Ashleigh M. Maxcey (she/her) was invited to contribute this chapter by the editors, co-wrote the first draft, and oversaw all reported novel experiments in her laboratory.

Elizabeth Mancuso (she/her) and Emily Spinelli (she/her) ran *Forgetting negative visual memories occurs after activating related negative memories* and provided feedback on the chapter.

Paul S. Scotti (he/him) programmed, ran, and analyzed *Induced forgetting is a within-category forgetting effect* and *Recognition-induced forgetting operates across networks of semantically, not perceptually, linked visual memory representations*. Paul also provided feedback on the chapter.

Geoffrey F. Woodman (he/him) co-wrote the chapter and is responsible for many stimulating conversations advancing induced forgetting, including the Christmas tree model.

References

Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology*, *6*(4), 451–474.

Anderson, J. R. (2009). *Cognitive psychology and its implications* (7th ed.). Worth Publishers.

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language*, *49*, 415–445. https://doi.org/10.1016/j.jml.2003.08.006

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(5), 1063–1087. https://doi.org/10.1037//0278-7393.20.5.1063

Bainbridge, W. A. (2020). The resiliency of image memorability: A predictor of memory separate from attention and priming. *Neuropsychologia*, *141*, 107408.

Barber, S. J., & Mather, M. (2012). Forgetting in context: The effects of age, emotion, and social factors on retrieval-induced forgetting. *Memory & Cognition*, *40*(6), 874–888. https://doi.org/10.3758/s13421-012-0202-8

Barnier, A., Hung, L., & Conway, M. (2004). Retrieval-induced forgetting of emotional and unemotional autobiographical memories. *Cognition and Emotion*, *18*(4), 457–477. https://doi.org/10.1080/0269993034000392

Bauml, K. H., & Kuhbandner, C. (2007). Remembering can cause forgetting--but not in negative moods. *Psychological Science*, *18*(2), 111–115. https://doi.org/10.1111/j.1467-9280.2007.01857.x

Bell, R., Maxcey, A. M., & Loftus, E. F. (2018). Crime solving: Can you correctly report what you saw? *Frontiers for Young Minds*, *6*(21). https://doi.org/10.3389/frym.2018.00021

Bjork, R. A. (1972). Theoretical implications of directed forgetting. In A. W. Milton & E. Martin (Eds.), *Coding processes in human memory* (pp. 217–235). V. H. Winston & Sons, Inc.

Bjork, R. A., Laberge, D., & Legrand, R. (1968). The modification of short-term memory through instructions to forget. *Psychonomic Science*, *10*(2), 55–56.

Brown, J. (1954). The nature of set-to-learn and of intra-material interference in immediate memory. *Quarterly Journal of Experimental Psychology*, *6*(4), 141–148.

Coman, A., Manier, D., & Hirst, W. (2009). Forgetting the unforgettable through conversation socially shared retrieval-induced forgetting of September 11 memories. *Psychological Science*, *20*(5), 627–633. https://doi.org/10.1111/j.1467-9280.2009.02343.x

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*, 671–684.

Dehli, L., & Brennen, T. (2009). Does retrieval-induced forgetting occur for emotional stimuli? *Cognition and Emotion*, *23*(6), 1056–1068.

Detre, G. J., Natarajan, A., Gershman, S. J., & Norman, K. A. (2013). Moderate levels of activation lead to forgetting in the think/no-think paradigm. *Neuropsychologia*, *51*(12), 2371–2388. https://doi.org/10.1016/j.neuropsychologia.2013.02.017

Epstein, W. (1972). Mechanisms of directed forgetting. In *Psychology of learning and motivation* (Vol. 6, pp. 147–191). Elsevier.

Ford, C. B. (2018, September 27) *Kavanaugh hearing: Transcript*. Bloomberg Government.

Fukuda, K., Pall, S., Chen, E., & Maxcey, A. M. (2020). Recognition and rejection independently induce forgetting. *Psychonomic Bulletin & Review*. https://doi.org/10.3758/s13423-020-01714-x

Glanzer, M., & Cunitz, A. R. (1966). Two storage mechanisms in free recall. *Journal of Verbal Learning and Verbal Behavior*, *5*(4), 351–360.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, *5*(9), 394–400.

Hauer, B. J. A., & Wessel, I. (2006). Retrieval-induced forgetting of autobiographical memory details. *Cognition and Emotion*, *20*(3–4), 430–447. https://doi.org/10.1080/02699930500342464

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, *110*, 306–340.

Jonker, T. R., Seli, P., & MacLeod, C. M. (2013). Putting retrieval-induced forgetting in context: An inhibition-free, context-based account. *Psychological Review*, *120*(4), 852–872. https://doi.org/10.1037/a0034246

Kuhbandner, C., Bäuml, K.-H., & Stiedl, F. C. (2009). Retrieval-induced forgetting of negative stimuli: The role of emotional intensity. *Cognition and Emotion*, *23*(4), 817–830. https://doi.org/10.1080/02699930802204768

Lang, P. J. (2005). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical report.

Lewis-Peacock, J. A., & Norman, K. A. (2014). Competition between items in working memory leads to forgetting. *Nature Communications*, *5*(1), 5768. https://doi.org/10.1038/ncomms6768

Loftus, E. F., & Palmer, J. C. (1974). Reconstruction of automobile destruction: An example of the interaction between language and memory. *Journal of Verbal Learning & Verbal Behavior*, *13*(5), 585–589. https://doi.org/10.1016/s0022-5371(74)80011-3

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, *95*, 492–527.

MacLeod, C. M. (2012). Directed forgetting. In *Encyclopedia of the Sciences of Learning* (pp. 993–995). Springer.

Maxcey, A. M. (2016). Recognition-induced forgetting is not due to category-based set size. *Attention, Perception, & Psychophysics*, *78*(1), 187–197. https://doi.org/10.3758/s13414-015-1007-1

Maxcey, A. M., & Bostic, J. (2015). Activating learned exemplars in children impairs memory for related exemplars in visual long-term memory. *Visual Cognition*, *23*(5), 643–558. https://doi.org/10.1080/13506285.2015.1064052

Maxcey, A. M., Bostic, J., & Maldonado, T. (2016). Recognition practice results in a generalizable skill in older adults: Decreased intrusion errors to novel objects belonging to practiced categories. *Applied Cognitive Psychology*, *30*(4), 643–649. https://doi.org/10.1002/acp.3236

Maxcey, A. M., De Leon, V. I., Janakiefski, L., Megla, E., Stallkamp, S. J., Torres, R. E., . . . Fukuda, K. (2021). Induced forgetting of pictures across shifts in context. *Journal of Experiment Psychology: Human Perception & Performance, 47*(8), 1091–1102.

Maxcey, A. M., Dezso, B., Megla, E., & Schneider, A. (2019). Unintentional forgetting is beyond cognitive control. *Cognitive Research: Principles and Implications*, *4*(1), 25. https://doi.org/10.1186/s41235-019-0180-5

Maxcey, A. M., Glenn, H., & Stansberry, E. (2018). Recognition-induced forgetting does not occur for temporally grouped objects unless they are semantically related. *Psychonomic Bulletin & Review*, *25*(3), 1087–1103. https://doi.org/10.3758/s13423-017-1302-z

Maxcey, A. M., Janakiefski, L., Megla, E., Smerdell, M., & Stallkamp, S. (2019). Modality-specific forgetting. *Psychonomic Bulletin & Review*, *26*(2), 622–633. https://doi.org/10.3758/s13423-019-01584-y

Maxcey, A. M., McCann, M., & Stallkamp, S. (2020). Recognition-induced forgetting is caused by episodic, not semantic, memory retrieval tasks. *Attention, Perception, & Psychophysics*. https://doi.org/10.3758/s13414-020-01987-3

Maxcey, A. M., & Woodman, G. F. (2014). Forgetting induced by recognition of visual images. *Visual Cognition*, *22*(6), 789–808. https://doi.org/10.1080/13506285.2014.917134

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review*, *88*, 375–407.

McNamara, T. P. (2005). *Semantic priming: Perspectives from memory and word recognition*. New York, NY: Psychology Press.

Megla, E., & Woodman, G. F. (under review). Medium strength visual long-term memories are the most fragile.

Megla, E., Woodman, G. F., & Maxcey, A. M. (2021). Induced forgetting is the result of true forgetting, not shifts in decision-making thresholds. *Journal of Cognitive Neuroscience*. https://doi.org/10.1162/jocn_a_01701

Muther, W. S. (1965). Erasure or partitioning in short-term memory. *Psychonomic Science*, *3*(1-12), 429–430.

Norman, K. A., Newman, E. L., & Detre, G. (2007). A neural network model of retrieval-induced forgetting. *Psychological Review*, *114*(4), 887–953. https://doi.org/10.1037/0033-295X.114.4.887

Nosofsky, R. M. (2011). The generalized context model: An exemplar model of classification. In *Formal approaches in categorization* (pp. 18–39).

Phelps, E. A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. *Current Opinion in Neurobiology*, *14*(2), 198–202.

Polyn, S. M., Norman, K. A., & Kahana, M. J. (2009). A context maintenance and retrieval model of organizational processes in free recall. *Psychological Review*, *116*(1). https://doi.org/10.1037/a0014420

Roediger, H. L., & Schmidt, S. R. (1980). Output interference in the recall of categorized and paired-associate lists. *Journal of Experimental Psychology: Human Learning and Memory*, *6*(1), 91.

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian t-tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review*, *16*(2), 225–237. https://doi.org/10.3758/PBR.16.2.225

Rugo, K. F., Tamler, K. N., Woodman, G. F., & Maxcey, A. M. (2017). Recognition-induced forgetting of faces in visual long-term memory. *Attention, Perception, & Psychophysics*, *79*(7), 1878–1885. https://doi.org/10.3758/s13414-017-1419-1

Scotti, P. S., Janakiefski, L., & Maxcey, A. M. (2020). Recognition-induced forgetting of thematically-related pictures. *Psychonomic Bulletin & Review*. https://doi.org/10.3758/s13423-019-01693-8

Scotti, P. S., & Maxcey, A. M. (2021). What do laboratory-forgetting paradigms tell us about use-inspired forgetting? *Cognitive Research: Principles and Implications, 6*(37), 1–10. https://doi.org/10.1186/s41235-021-00300-6

Sederberg, P. B., Howard, M. W., & Kahana, M. J. (2008). A context-based theory of recency and contiguity in free recall. *Psychological Review*, *115*(4), 893.

Spinelli, E., Janakiefski, L., & Maxcey, A. M. (under review). Using recognition-induced forgetting to assess forgetting of racial minority faces.

Standing, L. (1973). Learning 10,000 pictures. *Quarterly Journal of Experimental Psychology*, *25*, 207–222. https://doi.org/10.1080/14640747308400340

Stone, C. B., Barnier, A. J., Sutton, J., & Hirst, W. (2013). Forgetting our personal past: Socially shared retrieval-induced forgetting of autobiographical memories. *Journal of Experimental Psychology: General*, *142*(4), 1084.

Storm, B. C., & Jobe, T. A. (2012). Retrieval-induced forgetting predicts failure to recall negative autobiographical memories. *Psychological Science*, *23*(11), 1356–1363. https://doi.org/10.1177/0956797612443837

Storm, B. C., & Levy, B. J. (2012). A progress report on the inhibitory account of retrieval-induced forgetting. *Memory and Cognition*, *40*(6), 827–843. https://doi.org/10.3758/s13421-012-0211-7

Taylor, J. (2001). Linguistics: Prototype theory. In N. J. Smelser & P. B. Baltes (Eds.), *International encyclopedia of the social & behavioral sciences* (pp. 8954–8957). Elsevier Inc.

Tulving, E., & Arbuckle, T. Y. (1963). Sources of intratrial interference in immediate recall of paired associates. *Journal of Verbal Learning and Verbal Behavior*, *1*(5), 321–334.

Tulving, E., & Arbuckle, T. Y. (1966). Input and output interference in short-term associative memory. *Journal of Experimental Psychology*, *72*, 145–150.

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review*, *64*, 49–60.

Vogel, E. K., Woodman, G. F., & Luck, S. J. (2005). Pushing around the locus of selection: Evidence for the flexible-selection hypothesis. *Journal of Cognitive Neuroscience*, *17*(12), 1907–1922.

Yonelinas, A. P., & Ritchey, M. (2015). The slow forgetting of emotional episodic memories: An emotional binding account. *Trends in Cognitive Sciences*, *19*(5), 259–267.