A Review of Retrieval-Induced Forgetting in the Contexts of Learning, Eyewitness Memory, Social Cognition, Autobiographical Memory, and Creative Cognition

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Abstract

Retrieving information from memory can cause the forgetting of other information in memory, a phenomenon referred to as retrieval-induced forgetting. Over the past 20 years, retrieval-induced forgetting has been observed in a variety of experimental contexts and has been argued to impact a number of cognitive and psychological processes. Not simply a laboratory phenomenon, retrieval-induced forgetting appears to have important implications for furthering our basic understanding of memory and behavior. In the present chapter, we provide a selective review of retrieval-induced forgetting in five contexts—learning and education, eyewitness memory, social cognition, autobiographical memory, and creative cognition—and discuss the importance of studying retrieval-induced forgetting in situations beyond the typical retrieval-practice paradigm.

1. INTRODUCTION

Over two decades ago, Michael Anderson, Robert Bjork, and Elizabeth Bjork (1994) published a paper entitled “Remembering Can Cause Forgetting: Retrieval Dynamics in Long-Term Memory.” The paper presented evidence of a relatively simple phenomenon using a relatively simple paradigm. To put it succinctly, retrieving a subset of items from a category caused the forgetting of other items from that category, a finding referred to as retrieval-induced forgetting. Although there had already been a rich history of research on the detrimental consequences of retrieving some items from memory on the later recall of other items in memory (e.g., Blaxton & Neely, 1983; Brown, 1981; Roediger & Schmidt, 1980; Roediger, 1974, 1978; Rundus, 1973; Tulving & Arbuckle, 1966), the paper by Anderson and colleagues inspired a new wave of research, set to
explore the dynamics of retrieval-induced forgetting in new and exciting ways, rich with theoretical and applied implications.

The literature is now rife with theoretical reviews focused on how and why retrieval-induced forgetting is observed (see, e.g., Anderson & Levy, 2007; Anderson, 2003; Bäuml, 2007; Levy & Anderson, 2002; Raaijmakers & Jakab, 2013; Storm & Levy, 2012; Verde, 2012), with debate focused predominantly on inhibitory-based versus noninhibitory-based explanations (for a recent meta-analysis, see Murayama, Miyatsu, Buchli, & Storm, 2014). To date, however, there have not been any systematic reviews of the various applications of retrieval-induced forgetting as they relate to other psychological processes and the way in which we think, behave, and remember more generally. This lacuna is surprising given the amount of relevant research that has attempted to extend the boundaries of the retrieval-practice paradigm. The purpose of the current chapter is to review the role and implications of retrieval-induced forgetting in five distinct contexts: learning and education, eyewitness memory, social cognition, autobiographical memory, and creative cognition. In the final section, we take a broader perspective and discuss a few overarching issues for future research to consider.

2. RETRIEVAL-INDUCED FORGETTING: THE PHENOMENON AND THEORETICAL ACCOUNTS

Although retrieval-induced forgetting has been explored in many ways and with many materials, most research have employed some variant of the retrieval-practice paradigm developed by Anderson, Bjork, and Bjork (1994). In this paradigm, illustrated in Figure 1, participants first study a list of category–exemplar pairs (e.g., fruit–orange, metal–silver, fruit–banana, metal–copper), often consisting of several exemplars from several categories. Participants are then presented with category-plus-stem retrieval cues associated with half of the exemplars from half of the categories (e.g., fruit-or______). Participants are instructed to use the cues to retrieve the appropriate exemplars from the earlier study list. Retrieval practice often consists of several rounds of trials, with participants retrieving the to-be-practiced exemplars multiple times. Finally, after a brief delay (usually 5–20 min), participants are tested on their ability to retrieve the items from the study phase.

This retrieval-practice paradigm creates three types of items: Rp+ items, Rp− items, and Nrp items. Rp+ items are exemplars generated during
retrieval practice (i.e., orange); Rp— items are nonpracticed exemplars from practiced categories (i.e., banana); and Nrp items are nonpracticed exemplars from nonpracticed categories (i.e., silver & copper). Not surprisingly, when assessed at final test, Rp+ items are recalled best, presumably owing to the benefits of testing that have been shown to enhance long-term memory (see Bjork, 1975; Roediger & Karpicke, 2006). The more important finding, at least in the current context, is that Rp— items are recalled less well than Nrp items. It is this diminished accessibility of Rp— items relative to Nrp items that is referred to as the empirical phenomenon of retrieval-induced forgetting (Anderson et al., 1994).

Although we now suffer from the hindsight bestowed by 20 years of research on retrieval-induced forgetting, it is important to note that there were reasons to think that the accessibility of Rp— items might profit, not suffer, from the retrieval practice of Rp+ items. The idea of spreading activation, for example, which is prominent in some associative models of memory, might predict that strengthening some exemplars of a category would strengthen
other exemplars of that category (e.g., Loftus, 1973; Warren, 1977). Indeed, participants might rehearse—overtly or covertly—related nontarget exemplars during retrieval practice, potentially making such items more recallable in the future than they would have been otherwise. Despite these possibilities, retrieval–induced forgetting has proven to be remarkably robust. According to Murayama et al. (2014) meta-analysis, the average effect size is 8.7% (CI95% = 7.5%, 9.8%), an estimate that probably underestimates the true effect size because the analysis included studies and manipulations that were specifically designed to prevent or even reverse the effect of forgetting.

In addition to semantically associated categories, retrieval-induced forgetting has been observed with visual scenes (e.g., Shaw, Bjork, & Handal, 1995), event narratives (e.g., MacLeod, 2002), visuospatial materials (e.g., Ciranni & Shimamura, 1999), propositions (e.g., Anderson & Bell, 2001), mathematic operations (e.g., Phenix & Campbell, 2004), motor actions (e.g., Tempel & Frings, 2013), goals (e.g., McCulloch, Aarts, Fujita, & Bargh, 2008), languages (Levy, McVeigh, Marful, & Anderson, 2007), scripts (Garcia-Bajos & Migueles, 2013), spatial locations (Gómez-Ariza, Fernández, & Bajo, 2012), phonological categories (Bajo, Gómez-Ariza, Fernández, & Marful, 2006), word-fragment completion tasks (Healey, Campbell, Hasher, & Ossher, 2010), self-performed actions (e.g., Sharman, 2011), and autobiographical memories (e.g., Barnier, Hung, & Conway, 2004), to name just a few examples. Furthermore, retrieval–induced forgetting has been found using a number of different final test formats, including category-cued recall, category-plus-stem-cued recall, and item recognition. There are conditions in which retrieval–induced forgetting is not observed, but by and large, the phenomenon has proven to be more the rule than the exception.

According to inhibition-based accounts of retrieval–induced forgetting, attempting to retrieve target items during retrieval practice (i.e., Rp+ items) triggers the inappropriate activation of related nontarget items (i.e., Rp− items), causing competition. Inhibition is argued to reduce the accessibility of the competing nontarget items, thus rendering them less recallable in the future than they would have been otherwise. In this way, inhibition is posited to function as an adaptive mechanism that causes the forgetting of nontarget items in order to facilitate the retrieval of target items (for reviews, see Anderson, 2003; Bäuml, 2007; Norman, Newman, & Detre, 2007; Storm & Levy, 2012).

Although most proponents of inhibition–based accounts agree that inhibition functions to resolve competition during retrieval practice, the specific
way in which it does so remains a topic of debate. For example, inhibition has been argued to act at the level of the representation, rendering nontarget items less accessible given any potential retrieval cue (Anderson & Spellman, 1995; Anderson, 2003). Inhibition has also been argued to act in a more cue-specific manner that reduces the accessibility of nontarget items specifically in relation to the cues that inappropriately activated them (Perfect et al., 2004). Of course, these two possibilities are not mutually exclusive. Furthermore, it is unclear exactly what cognitive and neural processes underlie inhibition. Whereas some have argued that inhibition is accomplished via the same type of frontally mediated executive control processes that control thought and behavior more generally (e.g., Levy & Anderson, 2002; Marsh, Sörgqvist, Beaman, & Jones, 2013; Román, Soriano, Gómez-Ariza, & Bajo, 2009), others have argued that inhibition could be supported by executive processes, but accomplished more locally in the medial temporal lobe (Norman et al., 2007).

According to noninhibitory-based accounts, inhibition is unnecessary to explain retrieval-induced forgetting (e.g., Jonker, Seli, & MacLeod, 2013; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Raaijmakers & Jakab, 2013; Verde, 2012). For example, Rp− items may suffer forgetting because of increased competition from Rp+ items at final test. More specifically, retrieval practice may strengthen Rp+ items, thus increasing the extent to which those items interfere with the recall of Rp− items. Recent work by Jonker and colleagues has suggested that retrieval practice may also induce a change in context between study and final test that makes it more difficult to retrieve Rp− items, presumably because participants are then inappropriately cued to search the retrieval-practice context instead of the study context for Rp− items, something they would be unlikely to do in their search for Nrp items.

Most proponents of inhibition-based accounts agree that noninhibitory mechanisms—such as those related to strength-based interference and contextual cuing—can lead to retrieval-induced forgetting. The question is whether noninhibitory mechanisms are sufficient to account for all observations of retrieval-induced forgetting. Several findings suggest they are not. For example, evidence pertaining to cue independence (e.g., Anderson & Spellman, 1995; Anderson, Green, & McCulloch, 2000; Weller, Anderson, Gómez-Ariza, & Bajo, 2013), competition dependence (e.g., Anderson et al., 1994; Shivde & Anderson, 2001; Storm, Bjork, & Bjork, 2007), strength independence (Anderson, Bjork, & Bjork, 2000;
Bäuml, 2002; Storm, Bjork, Bjork, & Nestojko, 2006), and individual differences (e.g., Aslan & Bäuml, 2011; Storm & Angello, 2010; Storm & White, 2010), as well as neurobiological work (e.g., Hanslmayr, Staudigl, Aslan, & Bäuml, 2010; Kuhl, Dudukovic, Kahn, & Wagner, 2007; Penolazzi, Stramaccia, Braga, Mondini, & Galfano, 2014), has provided strong support for the idea that inhibition plays at least some role in causing retrieval-induced forgetting. Although some researchers have failed to replicate these findings and/or disagreed with their interpretations (e.g., Jakab & Raaijmakers, 2009; Verde & Perfect, 2011; Williams & Zacks, 2001), the results of Murayama et al. (2014) meta-analysis suggest that much of the evidence supporting a role for inhibition remains on solid empirical ground (for a recent progress report on the inhibitory account, see Storm & Levy, 2012).

Obviously, specifying a more precise model of the theoretical mechanisms underlying retrieval-induced forgetting is paramount, not only for developing theories of memory and inhibition in cognition, but for understanding the ways in which the phenomenon might impact other cognitive and psychological processes, in the laboratory and beyond. That said, the applied implications of retrieval-induced forgetting need not be constrained by the particular theoretical mechanism(s) responsible for forgetting. Although researchers have paid much attention to determining the underlying theoretical mechanisms that produce retrieval-induced forgetting—and rightly so—the consequences of such forgetting may have significant implications regardless of the particular mechanism by which it is produced. Thus, the current review will focus on retrieval-induced forgetting in the broader sense (i.e., any forgetting caused by retrieval) and will not be limited to instantiations of forgetting believed to be the aftereffects of inhibition during retrieval practice.

It should be noted that the five areas of work reviewed in the present chapter represent only a sample of the ways in which retrieval-induced forgetting has the potential to influence our everyday lives and psychological functions. We selected these areas in part because they represent areas that have received substantial empirical attention, but also because they are of particular interest to us. We encourage readers to consider exploring other areas as well. It also deserves emphasis that our reviews are not meant to be exhaustive. Instead, we focus on a sample of relevant studies hoping to give the reader a glimpse at what is known, what is not known, and where research in each area might be headed.
3. RETRIEVAL-INDUCED FORGETTING AND THE USE OF TESTING IN EDUCATION

We begin by focusing on the potential implications of retrieval-induced forgetting for the use of testing in education. In recent years, researchers have increasingly championed the use of testing as a means of producing new learning. Research has shown that tests do more than measure memory—they modify memory (Bjork, 1975), rendering information retrieved during tests more recallable in the future than it would have been otherwise, and to an extent greater than that which would have been observed with additional study (e.g., Rawson & Dunlosky, 2011; Roediger & Butler, 2011; Roediger & Karpicke, 2006). A clear implication of this research is that testing has the potential to improve student performance on subsequent tests when the same information is tested again. In practice, however, instructors often do not test the same information multiple times. Instead, for example, they often opt to test some information on a quiz and then other (possibly related) information on a later exam (Fadler, Bugg, McDaniel, & Liu, 2014). Additionally, instructors hope—that at the conclusion of their course, and perhaps beyond—that students will remember more than just what was tested. From an educational standpoint, therefore, it is important to understand how retrieving some information on a test might influence the retention of other information that was not initially tested.

Retrieval-induced forgetting has been observed using a variety of education-like materials (e.g., Camp & De Bruin, 2008; Carroll, Campbell-Ratcliffe, Murnane, & Perfect, 2007; Chan, 2009; Little, Storm, & Bjork, 2011; Macrae & MacLeod, 1999). Macrae and MacLeod, for example, investigated retrieval-induced forgetting with a paradigm constructed to mimic an educational situation. Participants studied facts about two fictitious islands, Tok and Bilu (e.g., “The official language in Tok is French”; “Bilu’s only major export is copper”), and then practiced retrieving half of the facts about one of the islands. At final test, participants were less likely to recall the nonpracticed facts about the practiced island (Rp—items) than the nonpracticed facts about the nonpracticed island (e.g., Nrp items). Following this initial investigation, others have examined retrieval-induced forgetting with more elaborate educational materials, often with the goal of clarifying the conditions under which forgetting does, and does not, occur. Two conditions that appear to be particularly relevant in this context are the nature of the retention interval between retrieval practice and final test, and the extent to which to-be-learned information is integrated.
3.1 Delay and Integration

With regard to retention interval, there is some evidence that retrieval-induced forgetting is eliminated when the delay between retrieval practice and final test is longer than 24 h (e.g., Carroll et al., 2007; Chan, 2009; MacLeod & Macrae, 2001; Saunders, Fernandes, & Kosnes, 2009). The reduction in retrieval-induced forgetting over a delay was presumed because even if retrieval practice caused nonpracticed information to be forgotten initially, that forgetting might be reversed over time, thus allowing the non-practiced information to regain its initial accessibility. For educators and students alike, this reduction in forgetting over a delay would seem advantageous, limiting the potential deleterious effects of retrieval-induced forgetting. More recently, however, research has shown that retrieval-induced forgetting can persist across days or even a week (García-Bajos, Migueles, & Anderson, 2009; Migueles & García-Bajos, 2007; Storm, Bjork, & Bjork, 2012; Storm et al., 2006). The extent to which retrieval-induced forgetting persists remains an open question, but the results of Murayama et al. (2014) meta-analysis suggest that retrieval-induced forgetting may persist long after retrieval practice has taken place. Moreover, as some have noted, short-term effects of retrieval-induced forgetting can lead to long-term effects if the initial forgetting reduces the extent to which some information benefits from the positive consequences of subsequent retrieval and rehearsal (e.g., Storm et al., 2006).

With regard to the integration of to-be-learned information, a number of studies have shown that episodic or semantic integration of Rp+ and Rp− items can protect Rp− items from retrieval-induced forgetting (e.g., Anderson & McCulloch, 1999; Anderson, Green, et al., 2000; Goodmon & Anderson, 2011). Building on this evidence, several researchers have hypothesized that retrieval-induced forgetting should be reduced or eliminated using educational materials that foster the integration of to-be-learned information (Camp & De Bruin, 2008; Carroll et al., 2007; Chan, 2009; Little et al., 2011). For example, providing material in the form of coherent text might offer the integration necessary to protect nonpracticed information from being forgotten, whereas providing the same material in a random order (i.e., as facts) would not (as was observed in the aforementioned study by Macrae & MacLeod, 1999).

To address the influence of delay and integration with educationally relevant materials, Chan (2009) had participants read a passage about Toucans. Half of the participants read the passage intact (coherent
condition), whereas the other half read the passage as a series of random facts (randomized condition). Importantly, the individual sentences across the two conditions were identical. Participants were then tested on some of the information immediately, and then tested on that previously tested information as well as other related, but initially nontested information after either a 20-min or 24-h delay. In the randomized condition, retrieval-induced forgetting was observed after the 20-min delay, but not after the 24-h delay. In the coherent condition, retrieval-induced forgetting was not observed at all. In fact, participants in the coherent condition exhibited a significant retrieval-induced facilitation effect after 24 h (see also, Chan, McDermott, & Roediger, 2006).

The work of Chan and colleagues suggests that presenting information in the form of coherent prose can protect learners from retrieval-induced forgetting and even produce benefits in that information related to tested information becomes more recallable after a delay than it would have been otherwise. The costs associated with retrieval practice appear to dissipate with delay, whereas the benefits persist. Other researchers have come to similar conclusions in related lines of work, each showing that text, and particularly coherent text, can afford protection from forgetting (Little et al., 2011; Experiments 1 & 2; Camp & De Bruin, 2008; but see; Carroll et al., 2007). Interestingly, Carroll et al. (Experiment 1) found that expertise reduced retrieval-induced forgetting, possibly because experts (but not novices) were able to fit new information into a coherent mental model that protected it from forgetting. Thus, the susceptibility of certain educational materials to forgetting may depend heavily on students’ level of domain-specific knowledge.

### 3.2 The Role of Competition

Although learning information in the form of coherent prose may reduce retrieval-induced forgetting under certain circumstances, it does not always do so. In the aforementioned work investigating retrieval-induced forgetting for text materials (Chan, 2009; Chan et al., 2006), initially tested and untested information were not necessarily competitive. In fact, Chan and colleagues specifically designed the materials in such a way that thinking of one fact would have helped participants remember the other fact. Thus, given that competition between Rp+ and Rp− items is assumed to be necessary for retrieval-induced forgetting to occur (Anderson et al., 1994; Shivde & Anderson, 2001; Storm et al., 2007; for a review, see Storm & Levy, 2012)—at least according to inhibition-based accounts—it is not
surprising that Chan and colleagues failed to observe forgetting when their noncompetitive $R_{p+}$ and $R_{p-}$ items were integrated in coherent text.

Although competition is not always present in educational contexts, there are many situations in which it is (e.g., learning about different countries in a geography course, learning about different parts of the body in anatomy). Little et al. (2011; Experiment 3), for example, had participants study passages about the geography, climate, and people of six different regions of the world (e.g., lowest temperature, predominant ethnicity of people) and then practice recalling information about half of the regions. They found that trying to recall information about half of the regions impaired participants’ later ability to recall similar information about the other half of the regions. The information was presented in a coherent manner, but tested and untested information came from different passages, thus preventing the $R_{p+}$ and $R_{p-}$ items from being episodically or semantically integrated in a way that would protect them from forgetting. In fact, because similar types of information were learned in relation to each of the regions, there would have likely been considerable competition during the initial test such that participants would have needed to inhibit the information related to the climate of the untested regions, for example, to help them remember the information related to the climates of the tested regions.

More recently, Little, Bjork, Bjork, and Angello (2012) asked participants to read passages about the planet Saturn and Yellowstone National Park, constructed with information that was intended to be competitive (i.e., descriptions of several geysers, explorers, dates). Answering cued-recall questions about Yellowstone (e.g., the largest geyser) impaired participants’ ability to recall related but initially untested information about Yellowstone (e.g., about the oldest geyser), as compared to untested information pertaining to the other studied topic. Thus, even information from the same passage can suffer retrieval-induced forgetting if the information is competitive. Taken together, these findings suggest that coherent prose does not always protect to-be-learned information from retrieval-induced forgetting, pointing to competition between tested and untested information as a crucial factor in determining whether or not forgetting is observed.

### 3.3 Fostering Facilitation

So where does this leave us in terms of selective testing in educational contexts? One concern is that although (1) a noncompetitive relationship between tested and untested information, (2) coherence (e.g., in the form of text or expertise), and (3) long delays between retrieval practice and final
testing can reduce retrieval-induced forgetting or even lead to retrieval-induced facilitation, these attributes are not always present in educational contexts. For example, course material often consists of information that causes competition with other information, learners often lack expertise, and information is often studied in a manner that is not integrative (e.g., flash cards). And although teachers are unlikely to administer quizzes less than 24 h prior to a more comprehensive test (thus reducing the likelihood of retrieval-induced forgetting on that test), students often self-quiz (e.g., with flash cards or practice tests) right before the exam, thus rendering non-practiced information vulnerable to retrieval-induced forgetting.

The question then is, under these conditions, what can be done to reduce or even reverse retrieval-induced forgetting in classroom settings? Recent research has suggested two possibilities: first, offering a chance to restudy information after initial testing, and second, using alternative test formats that protect against forgetting. Results pertaining to work investigating these two possibilities are shown in Figure 2. To examine the former, using the regions of the world materials, Little et al. (2011; Experiment 4) demonstrated that although selective testing of some information induced the forgetting of information pertaining to other regions (as shown by the first pair of bars in panel A), when given a chance to restudy the untested

![Figure 2](image-url)

**Figure 2** Percentage of Rp— and Nrp items correctly recalled on a final test as a function of restudy condition (Panel A) and initial test type (Panel B). As shown in the first pair of bars in each panel, retrieval-induced forgetting was observed following a cued-recall test with no restudy opportunity. When restudy occurred following a cued-recall test, or when an initial multiple-choice test—rather than an initial cued-recall test—was given, forgetting was eliminated (in the left and right panels, respectively). Panel A is adapted from Little et al. (2011); Experiment 4, by permission from Taylor & Francis, Ltd. Panel B is adapted from Little et al. (2012); Experiment 1.
information again, forgetting was eliminated (as shown by the second pair of bars in panel A). These results are consistent with the findings of Storm, Bjork, and Bjork (2008), showing that items subjected to retrieval-induced forgetting and then restudied benefit more from such restudy than items that were not subjected to retrieval-induced forgetting. Thus, as long as the to-be-learned material is reviewed at a later time, initial effects of retrieval-induced forgetting may not only be inconsequential, but they may under some conditions be beneficial.

Pertaining to the use of alternative test formats, retrieval-induced forgetting can be eliminated and even reversed by using multiple-choice tests instead of cued-recall or free-recall tests (Little et al., 2012). To clarify, in addition to exploring whether forgetting might occur for competitive information presented in text when cued-recall tests are used, Little et al. (2012) examined whether multiple-choice tests might protect competitive information from retrieval-induced forgetting. Little et al. measured retrieval-induced forgetting for the answer to a related, but initially untested question when that answer had served as an incorrect alternative on an earlier multiple-choice question. For example, participants might have answered a multiple-choice question about the largest geyser in Yellowstone National Park, with four alternatives that were presented in the text: *Steamboat Geyser*, *Daisy Geyser*, *Castle Geyser*, and *Old Faithful*. Although answering a cued-recall question about the largest geyser on the initial test impaired one’s ability to answer the related question about the oldest geyser (as shown by the first pair of bars in panel B of Figure 2), answering a multiple-choice question for which the answer to the related question served as an incorrect alternative protected that information from being forgotten (as shown by the second pair of bars in panel B; Experiment 1) and even facilitated its later retrieval (Experiment 2). Little and Bjork (2010) provided evidence that such facilitation did not occur simply as a consequence of prior exposure to the answer in the form of an incorrect alternative. Moreover, pertaining directly to educational settings, Bjork, Little, and Storm (2014) recently found that answering multiple-choice quiz questions improved performance for related questions on a later exam in the context of an undergraduate research methods course.

### 3.4 Concluding Comments and Future Directions

Many questions remain about the implications of retrieval-induced forgetting in educational contexts. One potential positive role for retrieval-induced forgetting involves the unlearning of errors and misconceptions.
Students commonly enter science courses with misconceptions (diSessa, 1988), and the replacement of such misconceptions with appropriate conceptions is a critical goal in science education (Hammer, 1996). The question of whether misconceptions might be eliminated through intentional retrieval practice of appropriate conceptions (or information associated with them) would be an interesting avenue for future research.

That said, there is substantial evidence that retrieval practice can also cause the forgetting of information that one wants to remember (Bäuml & Samenieh, 2010; Storm et al., 2007), and there is some evidence, which we will discuss in more detail below in the section on eyewitness memory, that retrieval practice has the potential to make learners vulnerable to misinformation (e.g., Chan, Thomas, & Bulevich, 2009; Saunders & MacLeod, 2002). Thus, if earlier-learned information is forgotten due to the retrieval of new information, it is possible that the earlier-learned information would actually be more susceptible to misinformation and the introduction of misconceptions than it would have been otherwise. Clearly this is an important topic for researchers and educators to pursue—as retrieval may propagate, rather than eliminate, erroneous ideas.

Although we have discussed the effects of testing and retrieval on the individual, relevant dynamics occur in group settings as well. For example, students often work together in preparation for exams, quizzing each other or explaining course material to one another. And students may not need to engage in overt retrieval attempts to suffer forgetting, because one person’s recall has been shown to cause another person’s forgetting—a phenomenon referred to as socially shared retrieval-induced forgetting (e.g., Cuc, Koppel, & Hirst, 2007). Simply listening to and monitoring another person’s attempts to retrieve some subset of information may be sufficient to cause students to lose access to nonretrieved information. In fact, to provide an example, it is possible that asking one student to answer a question in class might have the potential to cause all students to forget related, nonretrieved information.

Finally, little work has examined retrieval-induced forgetting with more extensive practice, particularly across longer delays. Chan’s (2009) work suggests that retrieval-induced forgetting does not persist with longer delays, at least for educational materials and when the Rp+ items are only tested in one session, but other work suggests that retrieval-induced forgetting can persist (e.g., Storm et al., 2012). How repeated practice of certain information over days and weeks might lead to persistent forgetting of untested information is yet to be investigated. To the extent that untested items pertain to information that one wants to forget (e.g., misconceptions),
such retrieval practice may be quite beneficial for learning; to the extent that untested items pertain to information that one does not want to forget, however, such retrieval practice may serve as an impediment for learning.

4. RETRIEVAL-INDUCED FORGETTING AND EYEWITNESS MEMORY

The ability to remember witnessed events accurately and comprehensively is critical to the functioning of our justice system. When witnesses are inaccurate, or unable to recall certain events they have experienced, innocent suspects may be incarcerated, and guilty suspects can be set free. Unfortunately, the same processes (e.g., interference, inhibition, forgetting, and distortion) that underlie our imperfect memory for the types of information studied in the laboratory also underlie the encoding and retrieval of eyewitness events (MacLeod, 2002). The present section focuses on research examining whether retrieval-induced forgetting plays a role in producing eyewitness memory inaccuracies, and how such inaccuracies occur.

The likelihood of retrieval-induced forgetting affecting eyewitness memory seems quite high given that eyewitnesses are typically cued to recall only portions of a witnessed event. Although police interrogators, friends and family, and lawyers may try to be exhaustive in their questioning, it seems unlikely, if not impossible, that they would actually be able to do so. The extent to which questioning is limited in scope can be further exacerbated when interrogators become overly concerned with specific details of the crime, or when police are in the initial fact-gathering phase of an investigation. Moreover, because police do not have access to all of the details of a crime—which is why eyewitnesses are questioned in the first place—they are not able to ask the full range of questions that would elicit more complete recall. Thus, when officers question witnesses, they are likely to ask questions relevant to only a subset of the information from an incident.

For example, based on initial reports from the scene of a crime, an officer may ask a witness about certain objects (e.g., a purse that was reportedly stolen), but not about other objects later revealed to also be important (e.g., a backpack worn by the culprit). When direct questioning of this type is employed, police interrogations solicit incomplete retrievals from eyewitnesses, creating conditions similar to that of the retrieval-practice paradigm. If a witness recalls details about the stolen purse, access to details related to the culprit’s backpack may be impaired. When eyewitnesses retrieve selected aspects of an incident, other potentially important aspects of the incident...
may become subject to retrieval-induced forgetting. In support of these arguments, retrieval-induced forgetting has now been found in nearly a dozen published experiments involving laboratory proxies of eyewitness events (Camp, Wesstein, & De Bruin, 2012; García-Bajos et al., 2009; MacLeod, 2002; Migueles & García-Bajos, 2006, 2007, Experiment 2; Saunders & MacLeod, 2006; Shaw et al., 1995).

4.1 Methodology and Typical Results

The eyewitness retrieval-practice paradigm typically follows the approach devised by Shaw et al. (1995; described in more detail below), which involves some slight modifications of the original retrieval-practice paradigm (Anderson et al., 1994). First, in lieu of a list of category–exemplar pairs, the study phase involves narrative descriptions, pictures, or videos of fictional crime scenes. Second, instead of category-plus-two-letter-stem retrieval cues, the retrieval-practice phase usually involves a series of questions about specific features of the incident arranged in order of increasing difficulty. Finally, instead of category-plus-letter-stem-cued recall that controls for output interference (Roediger & Schmidt, 1980), the final test typically involves free recall or category-cued recall.

As shown in Table 1, experiments investigating retrieval-induced forgetting in eyewitness memory have typically used materials that approximate eyewitness incidents, such as narrative descriptions (Migueles & García-Bajos, 2006; Saunders & MacLeod, 2006), pictures (MacLeod, 2002; Shaw et al., 1995), or videos (Camp et al., 2012; García-Bajos et al., 2009; Migueles & García-Bajos, 2007; Odinot, Wolters, & Lavender, 2009) of fictional crime scenes. Experiments with narratives have described a house from which items were stolen (Saunders & MacLeod, 2006) and actions performed during a mugging of an elderly woman (Migueles & García-Bajos, 2006). Experiments employing pictures as study materials have shown items stolen from two houses (electrical goods and nonelectrical goods; MacLeod, 2002), women collecting money for a fraudulent fundraiser (MacLeod, 2002), and a bedroom from which objects (college textbooks and college sweatshirts) were stolen (Shaw et al., 1995). Videos used as study materials have depicted a person being robbed while withdrawing money from a cash machine (Camp et al., 2012; Migueles & García-Bajos, 2007), a bank robbery (García-Bajos et al., 2009), and events leading up to a car crash (Odinot et al., 2009). The mode of study does not appear to have an effect: Retrieval-induced forgetting has been observed, in some form, in every eyewitness context in which it has been investigated.
<table>
<thead>
<tr>
<th>Publication</th>
<th>Study mode &amp; materials</th>
<th>Type of information practiced</th>
<th>RIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camp et al. (2012)</td>
<td>Video of a robbery at a cash machine</td>
<td>Offender characteristics (haircut)</td>
<td>Yes</td>
</tr>
<tr>
<td>García-Bajos et al. (2009)</td>
<td>Video of a bank robbery</td>
<td>Actions performed during robbery (robber demands money)</td>
<td>Yes</td>
</tr>
<tr>
<td>MacLeod (2002, Exp 1)</td>
<td>Picture slides of objects stolen from houses</td>
<td>Household objects (microwave; bracelet)</td>
<td>Yes</td>
</tr>
<tr>
<td>MacLeod (2002, Exp 2)</td>
<td>Picture slides of a fraudulent charity collection</td>
<td>General details from the pictures</td>
<td>Yes</td>
</tr>
<tr>
<td>MacLeod and Saunders (2005)</td>
<td>Narratives about two house burglaries</td>
<td>Household objects (bookcase; armchair)</td>
<td>Yes</td>
</tr>
<tr>
<td>Migueles and García-Bajos (2006)</td>
<td>Script of actions from a mugging</td>
<td>Actions during a mugging (mugger threatens victim)</td>
<td>Yes &amp; No*</td>
</tr>
<tr>
<td>Migueles and García-Bajos (2007, Exp 1)</td>
<td>Video of a robbery at a cash machine</td>
<td>Actions during a robbery (robbers take a man’s money)</td>
<td>No</td>
</tr>
<tr>
<td>Migueles and García-Bajos (2007, Exp 2)</td>
<td>Video of a robbery at a cash machine</td>
<td>Offender characteristics (goatee; round face)</td>
<td>Yes</td>
</tr>
<tr>
<td>Odinot et al. (2009)</td>
<td>Video of events leading up to a car crash</td>
<td>General details from the video</td>
<td>No</td>
</tr>
<tr>
<td>Saunders and MacLeod (2002, Exp 1)</td>
<td>Narratives about two house burglaries</td>
<td>Household objects (computer; necklace)</td>
<td>Yes</td>
</tr>
<tr>
<td>Saunders and MacLeod (2002, Exp 2)</td>
<td>Narratives about two house burglaries</td>
<td>Household objects (computer; necklace)</td>
<td>Yes &amp; No**</td>
</tr>
<tr>
<td>Saunders and MacLeod (2006)</td>
<td>Narratives about two house burglaries</td>
<td>Household objects (telescope; guitar)</td>
<td>Yes</td>
</tr>
<tr>
<td>Shaw et al. (1995)</td>
<td>Picture slides of objects in a student’s apartment</td>
<td>Objects (college sweatshirts; college textbooks)</td>
<td></td>
</tr>
</tbody>
</table>

* RIF was observed for low- but not high-typicality Rp-items.
** RIF was observed on an immediate but not 24-h delayed final test.
4.2 Types of Eyewitness Information

Crime scenes consist of many types of information that are potentially important to criminal cases. Research has demonstrated that retrieval-induced forgetting can occur for at least three broad types of information relevant to eyewitness memory: objects present in the scene of a crime (MacLeod, 2002; Saunders & MacLeod, 2006; Shaw et al., 1995), offender characteristics (Camp et al., 2012; MacLeod, 2002, Experiment 2; Migueles & García-Bajos, 2006), and low-typicality actions performed by offenders during an incident (García-Bajos et al., 2009; Migueles & García-Bajos, 2006, 2007).

In the first published investigation of retrieval-induced forgetting in eyewitness memory, Shaw et al. (1995) told participants to imagine they noticed their wallet was missing when they were at a college party. Participants then viewed a series of images depicting the inside of a student’s apartment. The pictures included two categories of items—college textbooks and college sweatshirts—with eight items in each category. After viewing the images, participants were asked questions for half of the items from one of the two categories. This retrieval-practice phase included three rounds of increasingly difficult questions (e.g., Round 1: “Was there a Harvard sweatshirt on the desk?” Round 2: “Was there a gray sweatshirt on the desk? If so, what was the name of the university on that sweatshirt?” Round 3: “Were there any sweatshirts on the desk? What was written on those sweatshirts?”). After a 5-min delay, participants attempted to recall the items from each of the two categories (college textbooks and college sweatshirts). Clear evidence of retrieval-induced forgetting was observed. Specifically, nonpracticed objects from nonpracticed categories were recalled less well than were objects from practiced categories. Similar results have since been observed in later studies (e.g., MacLeod, 2002; Saunders & MacLeod, 2006). Importantly, this later work has also shown that retrieval-induced forgetting is observed when participants are not provided specific category labels for the objects, which may be more akin to real eyewitness experiences because police interrogators typically do not provide category cues to elicit a person’s recollection of a witnessed event.

Offender characteristics may also be susceptible to retrieval-induced forgetting. Sketch artists and other interrogators, for example, extensively question witnesses about the physical characteristics of perpetrators, and accuracy of these details often determines whether the correct suspect (i.e., the guilty perpetrator) is taken into custody. When an eyewitness recalls one physical feature of a perpetrator, does this cause other features to be
forgotten? To answer this question, Camp et al. (2012) showed participants a brief video of two perpetrators (Offender A and Offender B) robbing a person at a cash machine, followed by questions about half of the characteristics of one of the two offenders. The retrieval practice questions closely approximated the types of questions asked by police interrogators (e.g., “What kind of haircut did the offender have?”). As shown by subsequent recall performance, retrieval practice for some characteristics (e.g., the haircut of Offender A) caused the forgetting of other characteristics (e.g., the color of Offender A’s pants). Interestingly, forgetting was also observed for similar characteristics of the nonpracticed offender (e.g., the haircut of Offender B), suggesting that retrieval-induced forgetting can occur across categories with eyewitness materials (for additional examples of retrieval-induced forgetting of perpetrator characteristics, see MacLeod, 2002, Experiment 2; Migueles & García-Bajos, 2006).

Another important aspect of crime scenes is the actions performed by perpetrators as they commit crimes. Court decisions are often determined by the sequence of events, the exact wording used by an offender, or other actions performed, so accuracy for these details is important. In a series of studies, Migueles and colleagues (García-Bajos et al., 2009; Migueles & García-Bajos, 2006, 2007) have demonstrated an important boundary condition upon the influence of retrieval-induced forgetting in eyewitness memory. In their studies, offenders were depicted as performing actions that were either highly typical (“The bank robbers threaten the people at gunpoint”) or not highly typical (“A robber points his gun at a security guard’s neck”) of the type of crime they were depicted committing (a bank robbery, in this example). Retrieval-induced forgetting was found for low-typicality actions but not for high-typicality actions, a finding that the authors argued illustrates integration as a boundary condition of retrieval-induced forgetting (Anderson & McCulloch, 1999). That is, high-typicality actions are connected via a schema that many people hold in memory, and that schema may guide recall and protect nonpracticed details from impairment. Low-typicality actions may not be well integrated within existing schemas, thus leaving them susceptible to retrieval-induced forgetting.

4.3 Questions of Durability
How long does retrieval-induced forgetting last for eyewitness events? Most of the extant research examining retrieval-induced forgetting of eyewitness memory has involved very short delays (e.g., 5 min) between retrieval
practice and test (Camp et al., 2012; MacLeod, 2002; Migueles & García-Bajos, 2006; Saunders & MacLeod, 2006; Shaw et al., 1995), but real eyewitnesses can be questioned weeks or months before they have to recount their experience in court. If retrieval-induced forgetting following initial interrogation is short lived, then the justice system need not worry about this memory impairment in criminal cases, because it would not affect an eyewitness’s long-term recall. There are reasons to believe, however, that retrieval-induced forgetting of eyewitness information may not be short lived. Although the literature has been mixed (e.g., MacLeod & Macrae, 2001; Storm et al., 2012), retrieval-induced forgetting has been found to be surprisingly durable (Murayama et al., 2014).

There is also evidence in eyewitness experiments of retrieval-induced forgetting persisting as long as 1 week after practice questioning (García-Bajos et al., 2009), though a longer interval of 2 weeks did not produce an effect (Odinot et al., 2009). The long-term detrimental effects of retrieval-induced forgetting may be underestimated by the current literature, however, when typical interrogation procedures are considered. Eyewitnesses are often questioned repeatedly across many days, with the probable outcome that successfully retrieved information continues to be additionally strengthened, while information initially omitted from recall becomes further impaired during each new recollection attempt. After prolonged selective practice and selective strengthening—that is, by the time witnesses take the stand at trial—certain aspects of the crime are deeply strengthened, while others may be all but lost. In this sense, repeated retrieval practice over long periods of time may have a cascading effect on subsequent memory strengthening and integration that goes well beyond the initial effects of retrieval-induced forgetting, a possibility that research has yet to explore.

Another factor that does not bode well for the idea that eyewitnesses are likely to recover forgotten memories of an event is that retrieval-induced forgetting is observed not only on tests of recall, but on tests of recognition as well (e.g., Aslan & Bäuml, 2011; Hicks & Starns, 2004; Murayama et al., 2014; Román, et al., 2009; Verde, 2004). This finding suggests that eyewitnesses may not even be able to recognize aspects of witnessed events accurately following the selective retrieval practice of other aspects of those events. One might imagine that the ability to recognize forgotten information might vary as a function of the nature of the material, however, and it remains possible that such effects would not be observed in some eyewitness scenarios, such as with events or experiences that are highly distinct or emotionally salient.
4.4 Misinformation Effects

An area of particular interest to eyewitness researchers is the distortion of memory as a result of misleading statements or questioning. One interesting discovery is that retrieval-induced forgetting may leave forgotten information vulnerable to misinformation effects (MacLeod & Saunders, 2005, 2008; Saunders & MacLeod, 2002). The misinformation paradigm (cf. Loftus, Miller, & Burns, 1978), traditionally used to study misinformation effects, involves participants initially viewing a target event (e.g., a car stopping at a yield sign) followed by a questionnaire that subtly includes some misleading details about the event (e.g., a question asking about the car stopped at a stop sign). On a later memory test, misinformed participants choose the misinformation item (stop sign) instead of the original item (yield sign), while nonmisinformed participants choose the original item.

To study the influence of retrieval-induced forgetting on misinformation effects, Saunders and MacLeod (2002) combined the eyewitness retrieval-practice paradigm with the misinformation paradigm. In the eyewitness retrieval-practice portion of the experiment, participants read narratives containing information about items stolen from two households, were questioned about half of the items from one of the burgled households, and finally were asked to recall all of the items from both households. Following the free-recall phase, which demonstrated typical retrieval-induced forgetting effects, participants were asked questions about the initially read narratives. Within this question set, one question contained misinformation about one of the three item types (Rp+, Rp−, or Nrp). On a subsequent forced-choice recognition test, participants were more likely to choose the misinformation item when it had been introduced in reference to the Rp− item. Misinformation introduced about practiced items (Rp+ items) or about items from the nonpracticed burglary (Nrp items) was chosen at a rate comparable to those made by control participants who had received no retrieval practice for either burglary. This finding suggests that retrieval-induced forgetting may present a risk factor for memory distortion.

4.5 Concluding Comments and Future Directions

To understand the ramifications of retrieval-induced forgetting for memory of real events, one must consider two important facts about the interrogation of eyewitnesses: Questioning of eyewitnesses typically elicits incomplete recall of the critical incident and thus sets the stage for retrieval-induced forgetting of initially nonquestioned information, and eyewitnesses are often questioned
repeatedly between the critical incident and when they appear in court. The startling implication of the confluence of these two factors is that events not recalled by an eyewitness during the first interrogation may be very difficult to recover later. That is, those details that are initially recalled will continue to be recalled, while those details that are initially forgotten will continue to suffer additional forgetting. By the time an eyewitness takes the stand at trial, many details of the event may be lost. As such, one avenue that future research should pursue to gain additional ecological validity is to explore the consequences of selective retrieval in instances where eyewitnesses are questioned repeatedly, by many interrogators, and across many days.

Another important direction for future research to consider is whether retrieval-induced forgetting of offender characteristics alters lineup decision accuracy. To date, the eyewitness retrieval-practice paradigm has limited the final assessment of memory to free or cued recall of the type of information that was studied and practiced. Yet, one of the most crucial moments in eyewitness testimony is when the witness selects a suspect from a lineup, and lineup procedures are presently absent from the eyewitness retrieval-induced forgetting literature. If a witness is questioned in depth about the details of the offender’s face (e.g., by a sketch artist), does this partial retrieval alter that witness’s ability to accurately select the offender from a lineup? Does it alter the confidence with which the witness makes a lineup selection? It seems like these are among the most critical questions to be answered.

Ultimately, it may prove impossible to fully protect eyewitnesses from retrieval-induced forgetting. By asking a particular question first, for example, investigators may instantaneously act to bias subsequent recollections. Moreover, retrieval is not always externally induced. Eyewitnesses are likely to repeatedly retrieve events on their own, and the way in which they do so may be biased by their own personal expectations and prejudices. What the results of the research reviewed here tell us—if not how to prevent retrieval-induced forgetting in eyewitness contexts—is to better understand how eyewitness contexts are influenced by retrieval-induced forgetting. In this way, we may hopefully be better able to take such dynamics into account when assessing how eyewitnesses recall the events they claim to remember.

5. RETRIEVAL-INDUCED FORGETTING AND SOCIAL COGNITION

Memory is likely to play an important role in a variety of social processes (e.g., the way in which we interact with others, the types of
information we remember about others, and how we form and maintain impressions and judgments about others). Thus, to fully understand the implications of retrieval-induced forgetting, we must understand the way in which it has the potential to influence, as well as be influenced by, such processes. The particular information we remember about a given individual might determine, for example, the way in which we feel about that person or the way in which we interact with them. If retrieval-induced forgetting systematically alters the nature of what is accessible, then it may systematically influence social behavior. Moreover, retrieval-induced forgetting should not be studied—at least not exclusively—in a vacuum. Although experiments are often run individually in cubicle lab spaces, cognition is also instantiated socially, and social dynamics may influence how and when retrieval-induced forgetting takes place.

5.1 Information about Other People

There is now robust evidence that information about others is susceptible to retrieval-induced forgetting. In the first study to investigate this possibility, Macrae and MacLeod (1999) exposed participants to 10 relatively positive traits about each of two target individuals (e.g., “Bill is romantic and studious”; “John is artistic and generous”) and then provided participants with retrieval practice for 5 of the traits about one of the individuals. As has been shown in most other studies of retrieval-induced forgetting, this selective retrieval practice caused participants to forget the nonpracticed traits associated with the practiced individual. For example, retrieving the fact that Bill is romantic caused participants to forget that Bill is studious. Similar effects have since been observed in a variety of social contexts (e.g., Brazel & Ringqvist, 2009; Dunn & Spellman, 2003; Fernandes & Saunders, 2013; García-Bajos & Migueles, 2009; Iglesias-Parro & Gomez-Ariza, 2006; Lechuga, Gomez-Ariza, Iglesias-Parro, & Pelegrina, 2012; MacLeod & Macrae, 2001; Storm & Jobe, 2012a; Storm, Bjork, & Bjork, 2005). It is presently unclear whether certain types of social information are more susceptible to retrieval-induced forgetting than others, but some studies have suggested that negative information may be more susceptible to forgetting than positive information (e.g., Brazel & Ringqvist, 2009; Storm et al., 2005).

5.2 Stereotypes and Retrieval-Induced Forgetting

In a classic study of retrieval-induced forgetting, Dunn and Spellman (2003) exposed participants to stereotypic and individuating traits about
hypothetical individuals of specific stereotyped groups. An Asian woman, for example, was characterized as being “studious” and “wealthy” (where “studious” was the stereotypic trait and “wealthy” was the individuating trait), while a mother was characterized as being “patient” and “musical” (where “patient” was the stereotypic trait and “musical” was the individuating trait). Retrieval practice for one type of information (i.e., stereotypical or individuating) caused forgetting of the other type of information. At first glance, this finding appears to suggest that adjusting the type of information a person retrieves about someone has the potential to reduce or even eliminate the stereotypes they hold about that person. Unfortunately, as shown in panel A of Figure 3, Dunn and Spellman also found that when stereotypical beliefs were strong, the traits associated with those beliefs were less susceptible to forgetting, perhaps because such beliefs were well integrated within participants’ preexisting belief structures and social schemas.

In a later study, Quinn, Hugenberg, and Bodenhausen (2004) also found that stereotypical information modulated the effects of retrieval practice. Participants studied person–trait pairs (e.g., Susan-Confident) about two target individuals and then performed retrieval practice for half of the traits associated with one of the targets. The traits were either positive or negative and either stereotypic or nonstereotypic of one of two categories (i.e., athletes or feminists). When participants studied person–trait pairs without any knowledge of the stereotype that organized them, typical effects of retrieval-induced forgetting were observed. However, when participants were made aware of the stereotype, the retrieval-induced forgetting was significantly reduced. This finding suggests that adjusting the type of information retrieved can influence the extent to which stereotypes are held.
forgetting were observed for the stereotypic traits. When participants were informed of the stereotype (e.g., “Susan is a feminist”), however, the stereotypic traits that were affectively and stereotypically consistent with the practiced traits were protected from retrieval-induced forgetting. In fact, as shown in panel B of Figure 3, such traits actually exhibited significant retrieval-induced facilitation. These results lend additional support to the work of Dunn and Spellman (2003), suggesting that the stereotypes we hold may systematically influence the particular information we retain, biasing us toward remembering stereotypically consistent information and forgetting stereotypically inconsistent information.

5.3 Social Judgments, Behaviors, and Decision-Making

Does retrieval-induced forgetting, by manipulating the specific information that is accessible, have the power to influence our impressions, judgments, and decisions? Research has shown that metacognitive judgments are often influenced by how fluent or accessible certain information is in memory (e.g., Koriat, 1995, 1998). Thus, if retrieval-induced forgetting causes the selective forgetting of either positive or negative information about another person, for example, then perhaps judgments and decisions about that person would be influenced accordingly.

To investigate this possibility, Storm et al. (2005) had participants study personality traits (Experiment 1a) or behavior descriptions (Experiment 2) about four hypothetical individuals. Participants were shown pictures of the individuals and told they would be given the opportunity to interact with one of them later in the experiment, and that they should learn as much about them as possible. Critically, half of the traits or behavior descriptions about each individual were neutral (e.g., “Dave is lucky”; “Dave rides his bike to school”), whereas the other half were either positive (e.g., “Dave is generous”; “Dave runs errands for his elderly aunt”) or negative (e.g., “Dave is selfish”; “Dave tells lies to impress people”). After studying the items, participants received retrieval practice for the neutral traits, causing the retrieval-induced forgetting of the nonpracticed positive or negative traits. More importantly, however, when participants were asked to judge the individuals’ likability, such judgments were not influenced by whether the positive or negative information had been forgotten.

More recently, Brazel and Ringqvist (2009) found similar evidence using negative information that was even more salient (e.g., “beating up their kids”), showing that retrieval-induced forgetting failed to affect performance on an implicit attitude test for the targets. It is not immediately clear why
retrieval-induced forgetting failed to influence social judgments and implicit attitudes, but one possibility is that abstract judgments and impressions are to some degree distinct from our ability to retrieve certain information, even if that information led to the formation of such judgments and impressions in the first place (e.g., Klein, Loftus, & Kihlstrom, 1996; Klein, Loftus, & Plog, 1992). Moreover, judgments may often not be based on exhaustive attempts to retrieve relevant information. Rather, they may be made more spontaneously and based on gist (e.g., Brainerd & Reyna, 1990; Hastie & Park, 1986), which may make them less likely to be influenced by changes in accessibility owing to retrieval-induced forgetting.

Interestingly, other work has suggested that retrieval-induced forgetting can, at least under some conditions, influence social behavior and decision-making (Coman & Hirst, 2012; Coman, Coman, & Hirst, 2013; Fernandes & Saunders, 2013; Iglesias-Parro & Gomez-Ariza, 2006; Iglesias-Parro, Gómez-Ariza, & Arias, 2009; Lechuga, Gómez-Ariza, Iglesias-Parro, & Pelegrina, 2012). Iglesias-Parro and Gomez-Ariza (2006), for example, presented participants with candidates for a telephone insurance sales job. Two candidates were each described with three positive traits (e.g., “persuasive”) and three irrelevant traits (e.g., “single”). Then, during retrieval practice, participants were prompted to retrieve the irrelevant traits associated with one of the candidates. Prior to the final cued-recall test—which would later show evidence of retrieval-induced forgetting—participants were presented with pictures of the two candidates and asked to pick the one best for the job. Participants were most likely to select the candidate for whom the irrelevant traits had not been practiced, presumably because the positive traits associated with the other candidate had been forgotten.

Subsequent work has replicated this effect while demonstrating important boundary conditions. Iglesias-Parro et al. (2009), for example, found that rereading the irrelevant attributes (instead of retrieving them) of a given candidate was insufficient to bias decision-making, suggesting that active retrieval may be critical for the effect to be observed. More recently, in a study comparing younger and older adults, Lechuga et al. (2012) found that although both younger and older adults exhibited typical effects of retrieval-induced forgetting, only younger adults were influenced by such forgetting when making their decisions. One interpretation of this latter finding is that older adults may be less likely than younger adults to draw on details from memory when making decisions, perhaps because they rely more heavily on heuristic-based information when making social decisions (e.g., Kim & Hasher, 2005).
Taken together, these results suggest that retrieval-induced forgetting can affect social judgments and decision-making, but perhaps only when participants explicitly attempt to consider relevant information. Storm et al. (2005), for example, may have failed to find a significant effect of retrieval-induced forgetting on social judgments because participants were unlikely to attempt to remember the traits or behaviors associated with an individual when deciding whether or not they liked that individual. They might have instead formed a general impression and then let that impression guide their judgments. Had participants been asked to make judgments directly related to the studied information, then a very different pattern might have been observed.

5.4 Socially Shared Retrieval-Induced Forgetting

Thus far, we have focused on how retrieval-induced forgetting influences the way individuals remember social information, but there is also evidence that retrieval-induced forgetting itself can occur socially. For example, imagine that one person selectively retrieves a subset of information aloud from memory, while another person listens. Not only does this retrieval practice cause the remembering person to forget other nonretrieved information, it can also cause the listener to forget the nonretrieved information, a phenomenon referred to as socially shared retrieval-induced forgetting.

In the first study to demonstrate socially shared retrieval-induced forgetting, Cuc et al. (2007) found that when a speaker recalled some information, related but unrecalled information was more likely to be forgotten by the listener, but only when the listener monitored the speaker’s retrieval for accuracy. The first two experiments utilized a procedure very similar to that used in typical retrieval-induced forgetting studies, with retrieval practice being constrained by cued prompts (e.g., Experiment 1: Category–exemplar word pairs such as “Fruit: Ba____”; Experiment 2: Event-based stories, such as “Walked to school—pi____ up J____”). In Experiment 3, however, retrieval practice was left more unconstrained such that the speaker and listener took turns recalling, much in the same way that a conversation would unfold. Socially shared retrieval-induced forgetting was observed in all three experiments.

Socially shared retrieval-induced forgetting has now been observed many times, in many contexts, and with many types of remembering (Barber & Mather, 2012; Coman et al., 2013; Coman & Hirst, 2012; Cuc, et al., 2007; Coman, Manier, & Hirst, 2009; Koppel, Wohl, Meksin, & Hirst, 2014; Stone, Barnier, Sutton, & Hirst, 2013; for reviews, see Hirst.
As this body of work grows, it has become increasingly clear that understanding the way in which people remember and forget requires more than a consideration of the individual, but a consideration of social context as well. For example, studies have shown that people are less susceptible to socially shared retrieval-induced forgetting when they listen to an expert than when they listen to a nonexpert (Koppel et al., 2014), or when they listen to someone of the opposite sex than when they listen to someone of the same sex (Barber & Mather, 2012), presumably because such factors determine the extent to which listeners monitor and co-retrieve with other individuals.

5.5 Concluding Comments and Future Directions

Although the beliefs, judgments, and perceptions we make about others may not be tied directly to the accessibility of our memories, such processes would seem highly unlikely to function in a way that is completely independent from our memories. The particular information we remember (and forget) may help shape our social representations, allowing us to flexibly and adaptively update our judgments and perceptions over time. Whether and how retrieval-induced forgetting plays a role in this context remains to be seen. Something researchers should keep in mind, however, is that retrieval in real-world settings is much less constrained than the type of retrieval-practice tasks employed in the laboratory. What we think about and try to remember is determined not by the whims of an experimenter, but by our motivations, desires, and prejudices. Thus, the power of retrieval-induced forgetting to affect our judgments and perceptions may be determined to a large extent by our existing judgments and perceptions. An important implication of this consideration is that developing a more complete understanding of the way in which retrieval-induced forgetting influences social cognition will necessarily require a more complete understanding of the way in which social cognition influences retrieval-induced forgetting.

6. RETRIEVAL-INDUCED FORGETTING AND AUTOBIOGRAPHICAL MEMORY

Autobiographical memory has been argued to serve a number of functions, ranging from directive and social functions to those that have to do with how we represent ourselves and cope with adversity (Conway,
2005; Williams, Conway, & Cohen, 2008). Conway and Pleydell-Pearce (2000) model suggests that autobiographical memory is comprised of two key components: the working self and the autobiographical knowledge base. The working self includes an individual’s personal goals, while the autobiographical knowledge base contains memories of prior events and other episodic information accrued across the life span. The working self is presumed to activate certain information from the autobiographical knowledge base to satisfy its goals. Knowledge that is threatening or inconsistent with the self can be inhibited, for example, while knowledge that is comforting and consistent with the self can be maintained and consistently retrieved. If retrieval-induced forgetting plays a role in selectively facilitating, impairing, and shaping self-relevant memories, then clearly it would have important implications for understanding autobiographical memory.

6.1 Self-Relevant Memories

Is retrieval-induced forgetting observed with the type of complex semantic and episodic information associated with autobiographical memory? On the one hand, there are good reasons to think that autobiographical memories might be protected from retrieval-induced forgetting. Memories for personal experiences are self-relevant, often emotionally significant, and can be retrieved in response to a number of retrieval cues. Each of these factors may protect autobiographical memories from forgetting. Macrae and Roseveare (2002), for example, found that when participants imagined purchasing a number of items as gifts, retrieval practice for some of the items failed to cause the forgetting of other items. This protection was not observed, however, when participants imagined their best friend or a stranger purchasing the items as gifts. Macrae and Roseveare argued that self-relevance may offer protection from retrieval-induced forgetting through distinctive processing (see, e.g., Smith & Hunt, 2000). That is, self-relevant information may be encoded in such a way that makes it easily distinguishable from, and therefore not in competition with, other information in memory.

In contrast to the findings of Macrae and Roseveare (2002), later research has shown that autobiographical memories can and do suffer from retrieval-induced forgetting (e.g., Barnier et al., 2004; Harris, Sharman, Barnier, & Moulds, 2010; Hauer & Wessel, 2006; Jobe, 2012; Stone, Luminet, & Hirst, 2013; Stone, Barnier, et al., 2013; Stone, Luminet, et al., 2013). Barnier et al., for example, asked participants to generate autobiographical memories associated with positive, negative, and neutral category cues. Participants
were then guided to retrieve a subset of the memories associated with a subset of the cues, further elaborating on the memories as they did. This retrieval practice caused participants to forget—relative to baseline memories—the nonpracticed memories associated with the practiced categories, a forgetting effect that was observed for all types of autobiographical memories regardless of valence.

Interestingly, Hauer and Wessel (2006) conducted a similar study but found that whereas negative memories were susceptible to retrieval-induced forgetting, positive memories were not (see also, Harris et al., 2010). These results might be interpreted as suggesting that negative autobiographical memories are more susceptible to retrieval-induced forgetting than positive autobiographical memories, but such a finding has not been consistently observed across the literature. In any case, taken collectively, these and other studies suggest that self-relevant autobiographical memories are indeed susceptible to retrieval-induced forgetting, and that negative memories are no more protected from forgetting than are positive memories.

6.2 Individual Differences in Autobiographical Memory

In real-world contexts, the types of memories an individual retrieves are determined not by an experimenter, but by some combination of the cues that are available and the individual’s particular motivation and biases influenced by the working self. Although both positive and negative autobiographical memories may be susceptible to retrieval-induced forgetting, it is possible that in the natural functioning of autobiographical memory, negative memories may be more likely to be deemed unwanted or to-be-avoided, and thus more likely to be targeted by inhibition. In this way, retrieval-induced forgetting may help prevent unsettling, threatening, or even traumatic memories from reaching consciousness.

Storm and Jobe (2012b) explored this possibility by providing participants with a series of memory probes, such as “pool” and “medicine” (e.g., Crovitz & Shiffman, 1974), and asking them to recall either positive or negative events associated with the cues from their autobiographical past. Participants in the positive condition attempted to recall memories that made them “happy, proud, pleased, or gratified,” whereas participants in the negative condition attempted to recall memories that made them “sad, embarrassed, depressed, or hurt.” Storm and Jobe predicted that if retrieval-induced forgetting functions to keep negative autobiographical memories from coming to mind, then individual differences in forgetting
should correlate with the rate at which various types of autobiographical memories are recalled. To test this hypothesis, retrieval-induced forgetting was assessed using the typical retrieval-practice paradigm and then correlated with performance on the separate memory-probe task. As predicted, participants who exhibited higher levels of retrieval-induced forgetting recalled significantly fewer negative memories than participants who exhibited lower levels of retrieval-induced forgetting.

In a second experiment, Storm and Jobe (2012b) employed the same basic paradigm but asked participants to recall negative episodic memories from either childhood or the past month. A similar pattern was observed such that participants who exhibited low levels of retrieval-induced forgetting were more likely to recall negative events (from both contexts) than were participants who exhibited high levels of retrieval-induced forgetting. This correlation was observed even when limiting the sample to participants who were not depressed (scores of 13 or below on the BDI-II; Beck, Steer, & Brown, 1996), which is important given evidence that negative moods have the potential to reduce retrieval-induced forgetting (e.g., Bäuml & Kuhbandner, 2007). The scatterplot presented in panel A of Figure 4 shows the relationship between retrieval-induced forgetting and negative autobiographical recall collapsed across the two experiments.

Although speculative, given the results of Storm and Jobe (2012b), one might wonder if retrieval-induced forgetting is at least partially responsible

![Figure 4](image-url)

**Figure 4** Panel A shows recall performance for negative autobiographical memories as a function of individual differences in retrieval-induced forgetting across Experiments 1 and 2 in Storm and Jobe (2012b), $r = -0.32$, $p < 0.001$. Panel B shows recall performance for positive and negative autobiographical memories in Experiment 1 by individuals who exhibited the least amount of retrieval-induced forgetting vs individuals who exhibited average to high amounts of retrieval-induced forgetting. Data from Storm and Jobe (2012b).
for the positivity bias often observed in autobiographical memory (Bersten, 1996; Waldfogel, 1948; Walker, Showronsksi, & Thompson, 2003). Indeed, as shown in panel B of Figure 4, participants who exhibited average to high amounts of retrieval-induced forgetting exhibited normal positivity biases, whereas participants who exhibited low amounts of retrieval-induced forgetting failed to exhibit any positivity bias. We encounter retrieval cues all the time, and perhaps the inhibition underlying retrieval-induced forgetting helps keep negative memories associated with those retrieval cues from being consciously retrieved. Over time, this bias in retrieval practice may update the relative strength of positive and negative memories to make the former more accessible than the latter, a possibility that future research should explore.

6.3 Retrieval-Induced Forgetting and Depression

If retrieval-induced forgetting can function to keep negative memories from being retrieved, thus maintaining a positivity bias in autobiographical memory, then one might wonder if deficits in forgetting might be associated with symptoms such as anxiety, persistent sadness, intrusive negative thoughts, and rumination, each of which is associated with clinical depression (Nolen-Hoeksema, 2000; Watkins & Moulds, 2005). In fact, research has observed significant relationships between reductions in retrieval-induced forgetting and posttraumatic stress disorder (Amir, Badour, & Freese, 2009), anxiety (Law, Groome, Thorn, Potts, & Cuchanan, 2012; Saunders, 2012), and social phobia (Amir, Coles, Brigidi, & Foa; 2001), particularly when retrieval-induced forgetting is measured using the types of materials that individuals find distressing.

If a deficit in one’s susceptibility to retrieval-induced forgetting can lead to negativity biases in autobiographical memory, and to an increased propensity for experiencing anxiety and intrusive memories, then perhaps such a deficit stands as a significant risk factor for depression. In support of this hypothesis, correlations between retrieval-induced forgetting and depression have been observed. Groome and Sterkaj (2010), for example, found that 21 individuals diagnosed with clinical depression exhibited significantly less retrieval-induced forgetting than 21 control participants who were not clinically depressed. Similarly, in the study by Storm and Jobe (2012b), when data from participants suffering at least mild levels of depression were analyzed (i.e., scores of 14 or higher on the BDI-II; Beck et al., 1996), a significant correlation was observed such that individuals exhibiting the least retrieval-induced forgetting were significantly more depressed.
(as measured by severity on the BDI-II) than were individuals exhibiting the most retrieval-induced forgetting.

It is tempting to conclude that individual differences in susceptibility to retrieval-induced forgetting lead to individual differences in susceptibility to depression, perhaps mediated in part by the way in which forgetting affects autobiographical memory. However, strong evidence supporting this sort of causal relationship remains lacking. An alternative explanation might be that depression leads to changes and impairments in memory (e.g., Sternberg & Jarvik, 1976; Warren & Groome, 1984; Williams, 1996), which are then observed in the reduced levels of retrieval-induced forgetting. Several findings seem to support this alternative hypothesis. For example, retrieval-induced forgetting is significantly diminished when individuals not suffering from depression are placed in a negative mood (e.g., Bäuml & Kuhbandner, 2007) or under high amounts of stress (Koessler, Engler, Riether, & Kissler, 2009). Of course, it is possible that deficits in retrieval-induced forgetting and depression contribute to each other, leading to a cycle of negative remembering and negative feelings that continuously feed each other.

6.4 Remembering and Forgetting Trauma

There is evidence that individuals can experience serious trauma or abuse and then report an extensive period of time in which they do not remember it. Although such experiences clearly do occur, much less clear is how to interpret them (see, e.g., Anderson, 2001; Anderson & Huddleston, 2012; Briere & Conte, 1993; Freyd, 1996; Geraerts et al., 2007; Loftus & Davis, 2006; McNally & Geraerts, 2009; McNally, 2003; Schooler, Bendiksen, & Ambadar, 1997). We know that some recovered memories are likely to reflect memory constructions, particularly when memories have been recovered in the context of hypnosis, guided imagery, or related therapy-based procedures (e.g., Ceci & Loftus, 1994). There are instances, however, in which genuine traumatic experiences appear to be forgotten for an extended period of time and then later recovered.

One relevant piece of evidence in this contentious area of research is that the likelihood of forgetting traumatic childhood abuse varies as a function of the nature of the trauma. Victims are more likely to forget or have memory problems associated with trauma, such as childhood sexual abuse, when the perpetrator is a caregiver or member of the victim’s family than when the perpetrator is not (e.g., DePrince & Freyd, 2004; DePrince et al., 2012; Epstein & Bottoms, 2002; Freyd, 1996, 1999; Freyd, DePrince, & Zurbriggen, 2001). According to betrayal trauma theory (Freyd, 1996),
victims may experience memory problems in part because of the need to maintain attachment to someone who is important for their survival and development. Anderson (2001) has argued that retrieval-induced forgetting may play an important role in the forgetting associated with betrayal trauma. Because victims of child abuse are often forced to continue living with their abuser, they may have no means of escaping the cues that prompt memories of the abuse. And because victims often need to preserve attachment with their abuser and sustain their own emotional well-being, they may selectively retrieve nontraumatic memories in order to avoid the more threatening memories. Over time, this selective retrieval practice may render memories of abuse and trauma less accessible. The dynamics would be very different in cases where victims are abused by strangers. Although there would still be a strong motivation to not think about the trauma, there would not be the repeated exposure to triggering cues or the need to maintain attachment with the abuser.

6.5 Concluding Comments and Future Directions

One of the most underappreciated and poorly understood peculiarities of human memory is that remembering and forgetting—though widely regarded as distinct, opposing processes—are fundamentally interdependent (Bjork, 2011). This interdependency arises due to a curious asymmetry: Although humans have an astonishing capacity to store a virtually limitless amount of knowledge, the capacity to retrieve such information is severely limited (Bjork & Bjork, 1992). Although our limited capacity to retrieve may seem to reflect a failure of memory, it may be essential for updating memory over time, especially in the context of autobiographical memory. Retrieval-induced forgetting may act as a sort of memory modifier or updater, allowing outdated, unwanted, and irrelevant information to be set aside and thus facilitate the learning and remembering of new, desired, and relevant information.

Our ability to ensure a positivity bias in autobiographical memory, to keep unwanted or intrusive memories at bay, and to maintain a healthy and adaptive self-image, may depend, at least in part, on our ability to selectively forget. This is one of many reasons that recent investigations into individuals with highly superior autobiographical memory are so interesting (e.g., LePort et al., 2012; Parker, Cahill, & McGaugh, 2006). Such individuals appear to maintain extraordinary access to events and experiences from their past, an ability that is often characterized by them as both a blessing and a curse. It would be interesting to explore whether differences in retrieval-induced
forgetting (and inhibitory functioning more generally) play a role in this and other autobiographical memory phenomena.

7. RETRIEVAL-INDUCED FORGETTING AND CREATIVE COGNITION

Although retrieval-induced forgetting may have negative implications for the recall of the particular information being forgotten, it may have far more positive implications for the general functioning of cognition by enabling our ability to overcome interference and avoid perseverating on contextually inappropriate, prepotent responses (Anderson, 2003; Storm & Levy, 2012; Storm, 2011). Indeed, the inhibition underlying retrieval-induced forgetting may have the potential to facilitate performance on any cognitive task that requires one to select or generate a target response in the face of competition from other, nontarget responses. This adaptive form of forgetting may be particularly important for overcoming mental fixation. Steve Smith and colleagues have shown that our ability to think of new ideas and generate solutions to problems is often severely limited by the persistent accessibility of nontarget ideas and solutions, a phenomenon referred to as mental fixation (for reviews, see Smith, 2003, 2008; Smith & Ward, 2012). If retrieval-induced forgetting can help us to overcome fixation, then such a finding would suggest that it may significantly impact our ability to think, solve problems, and generate creative ideas.

In the retrieval-practice paradigm, the studied items are presumed to cause fixation during retrieval practice by interfering with access to the target items (e.g., Raaijmakers & Shiffrin, 1981; Rundus, 1973; Watkins & Watkins, 1975). In the context of creative cognition, old ideas and unhelpful representations are presumed to cause fixation by constraining thinking and preventing access to new ideas and new ways of thinking (e.g., Duncker, 1945; Luchins & Luchins, 1959; Maier, 1931; Smith & Blankenship, 1989, 1991; Smith, Ward, & Schumacher, 1993). In both contexts, inhibition may serve as a mechanism by which to overcome fixation, thus facilitating our ability to perform a broad array of cognitive tasks, such as remembering, thinking, and problem solving. Indeed, this framework would seem to predict that just as remembering causes forgetting, so should the more general act of thinking.

7.1 A Predictor of the Ability to Overcome Fixation

The inhibitory account of retrieval-induced forgetting assumes that forgetting is the consequence of a goal-directed mechanism that functions to
reduce interference, or mental fixation, during retrieval practice. If so, then it stands to reason that individuals who exhibit greater amounts of retrieval-induced forgetting should perform better on tasks that require interference or fixation to be overcome. Storm and Angello (2010) tested this hypothesis by examining the relationship between retrieval-induced forgetting and performance on a creative problem-solving task—specifically, the Remote Associates Test (RAT; Mednick, 1962). Their hypothesis was that if retrieval-induced forgetting reflects the ability to overcome fixation, then individuals who exhibit greater levels of retrieval-induced forgetting should also perform better on the RAT, but only under conditions of increased fixation.

Storm and Angello (2010) first measured individual differences in retrieval-induced forgetting using a semantic-generation version of the retrieval-practice paradigm (e.g., Bäuml, 2002; Storm et al., 2006). Then, in a separate phase of the experiment, participants attempted to solve 20 RAT problems. In the RAT, participants must generate a fourth word that is related to three cue words. The fourth word can be semantically related, form a common phrase, or be a synonym to each of the three cue words. For example, if lick, sprinkle, and mines are cue words for a given problem, then the correct solution would be salt, which forms the phrases salt lick and salt mines, and is closely related to sprinkle (salt is sprinkled on food). Critically, before attempting to solve the RAT problems, half of the participants studied cue–response pairs consisting of cues from the RAT problems and misleading associate responses that would not serve as viable solutions, thus inducing mental fixation (Smith & Blankenship, 1991). For example, participants studied lick–tongue, sprinkle–rain, and mines–rock, which would then increase the accessibility of the nontarget associates and impair participants’ ability to solve the RAT problems. The other half of the participants did not study these cue–response pairs (baseline condition), and thus would not suffer the same degree of fixation.

Prior work has shown that participants perform significantly worse in the fixation condition than in the baseline condition (Smith & Blankenship, 1991). The prediction made by Storm and Angello (2010), however, was that participants exhibiting higher levels of retrieval-induced forgetting would be better able to resolve fixation—and that is precisely what was observed. The extent to which participants suffered fixation was significantly predicted by individual differences in retrieval-induced forgetting. To illustrate, Storm and Angello split participants into two groups, those exhibiting low levels of retrieval-induced forgetting and those exhibiting high levels of
retrieval-induced forgetting. Participants exhibiting high levels of retrieval-induced forgetting were able to solve 93% of the problems in the fixation condition that were solved in the baseline condition, whereas participants exhibiting low levels of retrieval-induced forgetting were able to solve only 47% of the problems in the fixation condition that were solved in the baseline condition.

Koppel and Storm (2014) replicated and extended the work of Storm and Angello (2010) by examining whether an incubation period (i.e., a break) following an initial problem-solving attempt would alter the relationship between problem-solving performance and retrieval-induced forgetting. Incubation periods have been shown to reduce fixation (Smith & Blankenship, 1989, 1991). Thus, in the current context, the incubation period should make inhibition less important for overcoming fixation, and thus reduce the correlation between retrieval-induced forgetting and problem-solving success. To investigate this possibility, Koppel and Storm had participants attempt to solve 20 RAT problems for 60 s each. Half of the participants attempted to solve the problems for 60 consecutive seconds (continuous condition), whereas the other half attempted to solve the problems in two 30-s blocks separated by a 12-min break (distributed condition). Fixation was induced for all participants by having them study misleading cue–response pairs prior to problem solving. Replicating the earlier work, Koppel and Storm found that retrieval-induced forgetting correlated significantly with better performance during the initial 30 s of the problem solving (in both conditions). This correlation persisted in the final 30 s of the continuous condition, but was eliminated in the final 30 s of the distributed condition. Presumably, the incubation period provided in the distributed condition allowed fixation to dissipate on its own, thus obviating the role for the inhibition underlying retrieval-induced forgetting.

### 7.2 Problem-Solving-Induced Forgetting

If the inhibition underlying retrieval-induced forgetting does facilitate problem-solving performance by helping participants overcome fixation, then associates causing fixation should be susceptible to problem-solving-induced forgetting. Storm, Angello, and Bjork (2011) investigated this possibility by testing forgetting of misleading associates following RAT problem solving. Prior to solving a series of RAT problems, participants were exposed to a number of cue–response pairs (e.g., lick–tongue, sprinkle–rain, mines–rock, manners–polite, tennis–ball, and round–square). Critically, only half of the pairs contained misleading associates designed to cause fixation.
That is, half of the pairs consisted of cue words that would later be used to form the RAT problems (i.e., *lick, sprinkle, mines*), whereas half did not (i.e., *manners, tennis, round*). After attempting to solve the RAT problems, participants received a surprise final test for all of the cue–response pairs they had initially studied. As predicted, participants recalled fewer responses associated with cues encountered during problem solving than responses associated with cues that were not encountered during problem solving, thus demonstrating problem-solving-induced forgetting.

Storm et al. (2011) posited that the misleading associates were inhibited because they caused mental fixation, similarly to how exemplars are presumably inhibited during retrieval practice because they cause interference. In both situations, unwanted responses that have the potential to impede performance become less accessible in the future than they would have been otherwise. In subsequent experiments, Storm et al. showed that problem-solving-induced forgetting was observed even when participants failed to generate solutions during problem solving, and that the forgetting effect increased when participants spent more time attempting to solve the problems. Additionally, individuals who exhibited greater levels of problem-solving-induced forgetting performed better on a separate set of RAT problems than did individuals who exhibited reduced levels of problem-solving-induced forgetting. Interestingly, Storm and Koppel (2012) failed to find evidence of cue independence in problem-solving-induced forgetting—a finding that appears to set it apart from retrieval-induced forgetting.

### 7.3 Thinking-Induced Forgetting

If forgetting is a general consequence of thinking and solving problems, then it should not be limited to the context of RAT problems. To examine this possibility, Storm and Patel (2014) administered a modified version of the Alternative Uses Task (Guilford, 1967) in which participants attempted to think of uses for common household objects. In their paradigm, illustrated in panel A of Figure 5, participants studied four common uses associated with each of eight objects. For half of the objects, participants simply studied the uses and then went on to the next trial (baseline condition). For the other half of the objects, participants studied the uses before attempting to generate new uses for those objects (thinking condition). For the other half of the objects, participants studied the uses before attempting to generate new uses for those objects (thinking condition). Across several conditions and experiments, and as shown in the left hand bars of panel B, participants reliably recalled fewer studied items in the thinking condition than in the baseline condition, a phenomenon they referred to as
thinking-induced forgetting. Interestingly, a significant correlation was observed such that thinking-induced forgetting predicted the number of creative uses that participants were able to generate. That is, just as problem-solving-induced forgetting predicted the ability to solve problems—thinking-induced forgetting predicted the ability to generate creative ideas.

More recent work has shown that even our own ideas are susceptible to thinking-induced forgetting (Ditta & Storm, 2014). Specifically, participants were asked to think of four uses for an object before thinking of additional uses. Thinking of the additional uses caused participants to forget the initial uses they had generated, an effect that was observed even when participants were highly motivated to remember their initial uses. The only condition in which thinking-induced forgetting has not been observed is when participants are explicitly instructed to use either the studied uses (Storm & Patel, 2014; see the right hand bars of panel B in Figure 5) or the initially generated uses (Ditta & Storm, 2014) as hints to help them think of new uses. It is possible that forgetting is not observed under these conditions because both studied uses and initially generated uses do not cause fixation. That is, if ideas can serve as cues to mediate the generation of new ideas, then there should be no need to inhibit them. As reviewed earlier in this chapter, similar protective effects of interitem integration have been observed across the retrieval-induced forgetting literature (e.g., Anderson, Green, & McChullock, 2000; Chan et al., 2006; Goodmon & Anderson, 2011).

Figure 5 Panel A shows a schematic of the basic paradigm used by Storm and Patel to demonstrate thinking-induced forgetting. Panel B shows the results of Experiments 2a and 2b as a function of whether they used the studied uses as hints to guide their generation of new uses. Error bars represent standard errors of the mean. Panel B is adapted from Storm and Patel (2014).
7.4 Concluding Comments and Future Directions

Retrieval-induced forgetting, problem-solving-induced forgetting, and thinking-induced forgetting appear to share similar features, and they all seem to result, at least in part, from a mechanism acting to overcome fixation. It is important to emphasize, however, that each of these phenomena is likely to be multiply determined, and the extent to which different mechanisms account for the different phenomena is likely to vary as a function of factors such as context, the nature of the task, strategies, and individual differences. Although we have focused on inhibition as the explanatory mechanism, forgetting can also be caused by factors such as strength-based interference and context change. For example, generating new uses for an object might cause those uses to block access to the earlier-studied uses. Moreover, thinking of new uses may change the way in which an object is represented in memory, making the object a less effective cue for the recall of the originally studied uses. There is no reason to think that inhibition is the only mechanism underlying these phenomena, and future research should try to delineate the various mechanisms that contribute to the forgetting effects that have been observed.

Finally, some readers may be surprised that inhibition has the potential to facilitate creative thinking, especially because inhibition is more typically associated with reduced creative thinking (e.g., Carson, Peterson, & Higgins, 2003; Eysenck, 1995; Martindale, 1999). It seems to us that the relationship between inhibition and creative cognition is likely to be quite nuanced. Inhibition may stand to impair creativity when one inhibits information that might be novel or useful, but inhibition may stand to benefit creativity when one inhibits information that causes fixation and interferes with access to information that is novel and useful. These costs and benefits are likely to differ as a function of a number of factors, such as the nature of the particular task, but presumably the benefits should be greatest under conditions of fixation. If creativity is not contingent upon overcoming strong, irrelevant information in memory, and often it is not, then the role for inhibition and forgetting may be substantially diminished.

8. BROAD CONSIDERATIONS FOR THE STUDY OF RETRIEVAL-INDUCED FORGETTING IN CONTEXT

Albert Einstein (1933) once said: “It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple
and as few as possible without having to surrender the adequate representation of a single datum of experience.” This quote, sometimes referred to as Einstein’s razor (in contrast to Occam’s razor), contends that a theory should be made as simple as possible, but no simpler. Of course, whether a theory adequately represents every datum of experience depends not only on the soundness of the theory, but on the scope of the data collected to test it. As researchers, we tend to create paradigms to measure phenomena and then repeatedly mine those paradigms to develop theories. Implicitly assumed is that such theories will generalize beyond the paradigms, and in many cases they do. The danger arises when we become so enamored by a paradigm that we end up studying it as the target of interest, instead of the psychology it was created to tap into. Of course, using established and well-mined paradigms is important for a number of reasons, particularly with regard to experimental control and comparability between studies, but the unfortunate side effect is that we often limit our theories to explaining only a small slice of reality (for relevant discussions, see, e.g., Glenberg, 1997; Hintzman, 2011; Neisser, 1976; Watkins, 1990).

The goal of the present chapter was to highlight several attempts to move beyond the typical retrieval-practice paradigm to explore retrieval-induced forgetting in context. We believe that developing a comprehensive understanding of retrieval-induced forgetting requires a more thorough consideration of how it functions in real-world settings, and how it interacts with other psychological processes. Doing so may uncover new assumptions and new boundary conditions, and reshape the questions that need to be asked. Ultimately, most researchers are interested in retrieval-induced forgetting not because they want to know how and why retrieving one category exemplar causes the forgetting of another category exemplar in the context of a 25-min laboratory experience. Rather, they are interested in it because it has the potential to inform our basic understanding of how and why we remember and forget, and the role of such processes within the broad array of human experience.

The lines of work reviewed in the present chapter are still in their infancy. There are many questions that have yet to be answered and many more that have yet to be asked. On the basis of the evidence we have so far, however, several general observations deserve emphasis. First, retrieval-induced forgetting appears to be a decidedly robust and general phenomenon. With few exceptions, it has been observed in just about every context in which it has been explored—from educational settings, to eyewitness memory, to memory about oneself, and others. An important
limitation of this observation, however, is that the majority of the research that has observed retrieval-induced forgetting in these contexts has employed paradigms deviating only slightly or superficially from the typical retrieval-practice paradigm. Nevertheless, if these findings are taken at face value, retrieval-induced forgetting appears to impact basic cognitive and psychological processes. For example, retrieval-induced forgetting has been shown to predict one’s ability to solve problems, think of creative ideas, and remember relatively more positive than negative autobiographical memories, and it has been shown to impact the way in which we learn, provide testimony, and make decisions. In all certainty, the existing literature has only scratched the surface in terms of identifying such connections, and substantial work will be needed to more fully understand the connections that have been identified.

Some theoretical assumptions came up repeatedly across the chapter. Interitem integration, for example, which has been argued to reduce competition and thus diminish a nonpracticed item’s susceptibility to retrieval-induced forgetting (e.g., Anderson, Green, et al., 2000; Goodman & Anderson, 2011), was shown—or at least argued—to prevent forgetting in each of the five contexts we reviewed. Studying information in the form of coherent prose, using initial ideas as hints to guide the generation of new ideas, having expertise, or holding preexisting schemas and stereotypes, for example, were all shown to limit the extent to which retrieval-induced forgetting was observed. The generality of this effect suggests that integration will be an important factor for future researchers to consider in other contexts as well.

One factor that we believe should also be considered, even though it has not been the focus of much of the research covered in the present chapter, is that of cue independence. Cue independence reflects the finding that retrieval-induced forgetting is observed not only when nonpracticed items are tested via the same cues, but when tested via independent cues (e.g., Anderson & Spellman, 1995; Johnson & Anderson, 2004; Weller et al., 2013; but see, e.g., Camp, Pecher, & Schmidt, 2007; Perfect et al., 2004). The property of cue independence has been cited as strong evidence against noninhibitory accounts of retrieval-induced forgetting and as providing support for instantiations of inhibitory accounts that argue that inhibition affects items at the level of their representations. The importance and implications of cue independence may take a very different form, however, when considered beyond such theoretical distinctions and, more generally, beyond the confines of the typical retrieval-practice paradigm.
Consider, for example, the context of autobiographical memory. One of the hallmarks of memory—and especially autobiographical memory—is the extent to which recall depends on the specific cues and contexts that are available (see, e.g., Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Marian & Neisser, 2000; Smith & Moynan, 2008; Tulving & Thomson, 1973). Memories can go months if not years without being retrieved until just the right constellation of cues is encountered. Although speculative, one might contend that cue-specific forgetting would function more adaptively than cue-independent forgetting by shaping and updating autobiographical memory over time. Cue-specific forgetting would presumably render nonpracticed and unwanted memories less accessible in response to the cues that elicited them, while retaining the accessibility of such memories in other contexts and in response to other cues for which they would be desired and appropriate (for similar arguments about transfer-appropriate forgetting, see Perfect et al., 2004). Similar arguments can be made in other contexts. Information that causes fixation while solving one problem, for example, might remain useful for solving another problem, and a fact that is irrelevant to one test question might be very relevant to another test question. Cue-specific forgetting could act to resolve interference while simultaneously reshaping associative connections, thus preparing us to think and remember more effectively in the future. Note that this argument does not negate the importance or validity of cue-independent effects of retrieval-induced forgetting. Initial effects might be cue-independent but then cascade into cue-specific effects by biasing subsequent rehearsal and how information in long-term memory is integrated. The point is that whether a given real-world effect of retrieval-induced forgetting is cue independent or cue dependent should be investigated, though not necessarily for the purpose of distinguishing inhibitory and noninhibitory forms of forgetting.

A related question is whether and for how long effects of retrieval-induced forgetting persist. To date, the majority of research has examined this question in a very similarly constrained way. Specifically, participants study some information, receive a few short retrieval-practice attempts for a subset of that information, and are then tested after a few minutes, 24 h, or 1 week. Evidence has been mixed (e.g., Chan, 2009; MacLeod & Macrae, 2001; Storm et al., 2012; for a meta-analysis, see Murayama et al., 2014), but in the sense of trying to apply work on retrieval-induced forgetting to contexts beyond the retrieval-practice paradigm, the debate may be missing the point. In real-world contexts, retrieval practice is often far more extensive
than a few brief experimenter-cued trials, short-term effects can propagate to long-term effects, items are reencountered, new information is learned, and contexts are changed. To understand retrieval-induced forgetting in the context of the retrieval-practice paradigm, these factors need to be controlled. To understand the long-term influences of retrieval-induced forgetting in real-world settings, however, these factors need to be taken into account and investigated, something researchers have yet to do.

Finally, it deserves emphasis that retrieval-induced forgetting does not need to be the consequence of inhibition to have important implications for applied contexts and for informing our understanding of other psychological processes. If fixating information, painful autobiographical memories, educational materials, or details of a witnessed crime are forgotten as a result of retrieving certain information, for example, then such findings are important regardless of the underlying mechanisms. Obviously, understanding how and why forgetting occurs is important, but there can be a temptation to think that a finding is only interpretable if it can be directly connected to the theoretical accounts derived from more basic work in the laboratory. We would argue, however, that taking this perspective can be limiting, as the assumptions and methodological considerations relevant to making these sorts of theoretical distinctions often stand in contrast to obtaining the ecological validity necessary for meaningful and generalizable application.

Of course, attempts to employ the types of experimental controls needed to allow for interpretation within the context of existing theories should not be thrown to the wind; rather, studies should be designed with specific aims in mind. For example, the inhibition versus interference debate is directly relevant to many of the findings reviewed here. Research showing that individual differences in retrieval-induced forgetting are correlated with the ability to overcome fixation (Storm & Angello, 2010), for example, makes sense if forgetting is assumed to be the result of a goal-directed inhibitory process for overcoming competition; it does not make sense if forgetting is assumed to be the result of interference at test. Had Storm and Angello employed a methodology that measured retrieval-induced forgetting differently, such as in a way that failed to control for interference at test (see, e.g., Anderson & Levy, 2007; Murayama et al., 2014; Schilling, Storm, & Anderson, 2014; Soriano, Jiménez, Román, & Bajo, 2009), a different set of results would have likely been observed, and thus a different conclusion would have been made. Research has shown that retrieval-induced forgetting is likely to be a multifarious phenomenon driven by different mechanisms depending on
the particular way in which it is observed. Although we encourage researchers to move beyond the typical retrieval-practice paradigm, they should do so in a way that does not ignore the many important lessons that have been learned using that paradigm.

9. CONCLUSION

The present chapter has provided a brief review of five areas of research that have attempted to study retrieval-induced forgetting in context. Although we readily admit that the existing literature remains lacking, strides have been made, and we are hopeful that researchers will continue to advance these and other lines of work in new and interesting ways. In doing so, we believe the theoretical functions and dynamics of retrieval-induced forgetting will become more apparent. Rather than studying retrieval-induced forgetting as a specific phenomenon observed using a specific paradigm, we should study retrieval-induced forgetting as a family of phenomena impacting the ways in which we think and remember across a multitude of contexts. The prospect of undertaking this much broader form of empirical exploration and theoretical consideration may seem daunting, but will be ultimately necessary to more fully delineate the true nature and impact of retrieval-induced forgetting.

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