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Current Directions in Psychological Science 2011 20: 291
DOI: 10.1177/0963721411418469

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Current Directions in Psychological Science
20(5) 291–295

DOI: 10.1177/0963721411418469
http://cdps.sagepub.com
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The Benefit of Forgetting in Thinking and Remembering

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Abstract

Forgetting is a surprising and unintended consequence of remembering. Research on retrieval-induced forgetting has shown that retrieval of one item in memory can cause the forgetting of other items in memory. This forgetting is argued to be the consequence of an inhibitory process that underlies the ability to overcome interference during retrieval. The research reviewed here suggests that individuals who exhibit more retrieval-induced forgetting are more capable of overcoming interference in other contexts as well (e.g., creative problem solving). Ironically, it appears that thinking and remembering rely at least in part on a process that underlies forgetting.

Keywords

memory, forgetting, inhibition, interference, retrieval

When people hear that I study memory, a predictable conversation ensues: "Oh yeah, well you should study me! I have a *terrible* memory!" Typically what these individuals are referring to is the frustrating experience of not being able to recall the information they want at the time they want. After a little back and forth, I am usually able to convince them that their memory is in fact quite good, and that forgetting is for the most part adaptive. Imagine, for example, if memory functioned in such a way that everything ever encoded was made permanently accessible and that every cue ever encountered reminded you of everything that was encoded. As William James (1890, p. 680) wrote: "If we remembered everything, we should on most occasions be as ill off as if we remembered nothing."

People have a remarkable capacity to store information, which allows them to accumulate an impressive array of knowledge and expertise. Yet this storage capacity is paired with a fallible and highly cue-dependent retrieval process (Bjork & Bjork, 1992). An item accessible at one point in time and in response to one cue may become inaccessible at another point in time or in response to another cue. An important limitation on retrieval is the fact that multiple items can be associated with the same cue, and if a target item is less strongly associated with that cue than are other nontarget items, then the target item will suffer interference (Watkins & Watkins, 1975). For this reason, retrieval often fails not because an item has been lost in some permanent sense but because other items interfere, or get in the way. However, recent research on retrieval-induced forgetting suggests that we are not passive victims of interference; rather, we are armed with an inhibitory mechanism that facilitates retrieval by helping us overcome interference.

Overcoming Interference in Memory Retrieval

Memory researchers have known for some time that retrieval can impair or disrupt the subsequent recall of other information in memory (see, e.g., Roediger, 1974). One paradigm that has become popular in recent years for studying such dynamics is the retrieval-practice paradigm (Anderson, Bjork, & Bjork, 1994). Participants are exposed to a series of category–exemplar pairs followed by selective-retrieval practice for half of the exemplars from half of the categories. As measured on a subsequent final test, retrieval practice causes the retrieval-induced forgetting of nonpracticed exemplars from practiced categories (for a schematic of the paradigm, see Fig. 1). Several variations of the paradigm have become popular. For example, retrieval practice is sometimes replaced by a semantic-generation task in which participants are asked to retrieve nonstudied category exemplars from general knowledge rather than category exemplars from the earlier study phase. The nature of the final test has also varied. Whereas some studies have employed category cues at final test (e.g., "fruit?"), others have employed more restrictive, item-specific

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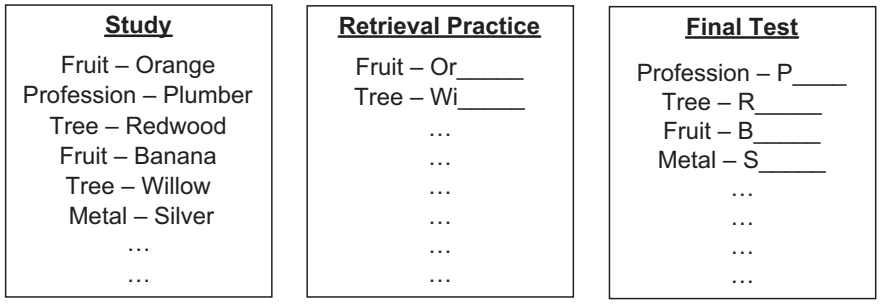

Fig. 1. Schematic of the standard retrieval-practice paradigm (Anderson et al., 1994). Participants first study category–exemplar pairs and then practice retrieval for half of the exemplars from half of the categories. Retrieval-induced forgetting is observed when nonpracticed exemplars from practiced categories ("banana" and "redwood") are subsequently recalled less well than nonpracticed exemplars from nonpracticed categories ("plumber" and "silver"). According to the inhibitory account of retrieval-induced forgetting, nonpracticed exemplars from practiced categories compete during retrieval practice and are inhibited to resolve that competition, thus rendering them less recallable on the final test.

cues (e.g., "fruit-b_____"), and others have even shown retrieval-induced forgetting using novel, or independent, retrieval cues (i.e., unrelated to the cue paired with the exemplar during study and retrieval practice; e.g., "monkey-b_____").

The inhibitory account contends that retrieval-induced forgetting is the consequence of an inhibitory process that resolves interference during retrieval (Anderson, 2003; Storm, 2011). According to this account, inhibition acts during retrieval practice to help participants overcome interference from competing nontarget items in order to facilitate the successful retrieval of target items. As a consequence of this inhibition, nontarget items become less recallable in the future than they would have been otherwise. Thus, retrieval-induced forgetting is the consequence of an adaptive mechanism that facilitates remembering by causing forgetting.

Although there is now substantial support for the inhibitory account, some memory theorists remain skeptical (e.g., MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). For example, one popular counterargument is that retrieval-induced forgetting may simply be the consequence of blocking or interference—that is, retrieval practice may strengthen a subset of items, making those items more likely to interfere with the recall of related nonpracticed items on the final test. Several lines of evidence provide a compelling case against this and other noninhibitory accounts (for reviews, see Anderson, 2003; Storm, 2011). For example, retrieval-induced forgetting has been shown to be strength independent. The interference account assumes that nonpracticed items are forgotten because practiced items are strengthened, yet the extent to which practiced items are strengthened does not determine the extent to which nonpracticed items are forgotten. In fact, strengthening the practiced items has proven to be neither sufficient nor necessary for retrieval-induced forgetting to occur (e.g., Bäuml, 2002; Storm, Bjork, Bjork, & Nestojko, 2006).

A more direct line of evidence supporting the inhibitory account has come from work showing that retrieval-induced forgetting is competition dependent. The inhibitory account assumes that inhibition acts to suppress nontarget items that compete with retrieval. Thus, if an item fails to compete during retrieval, then that item should not need to be inhibited. Studies manipulating competition during retrieval practice have supported this prediction, showing that the items that compete most with retrieval practice are most susceptible to being forgotten (e.g., Anderson et al., 1994; Storm, Bjork, & Bjork, 2007). For example, Storm et al. (2007) manipulated whether participants were told to remember or forget an initial list of items prior to receiving retrieval practice for other items. In light of research on directed forgetting, which has shown that telling participants to forget a list of items sharply reduces the extent to which those items interfere with the learning and recall of a second list of items, Storm and colleagues reasoned that telling participants to forget the first list would spare those items from needing to be inhibited and thus from suffering retrieval-induced forgetting. It did. Whereas to-be-remembered items suffered substantial retrieval-induced forgetting, to-be-forgotten items failed to suffer any retrieval-induced forgetting. Consistent with the inhibitory account, it was the items that competed most with retrieval that were most susceptible to being forgotten.

Overcoming Fixation in Creative Problem Solving

Unwanted and irrelevant items in memory can interfere with retrieval. Presumably, the inhibition underlying retrieval-induced forgetting helps us to overcome this interference. Yet retrieval is not the only context in which we are susceptible to the negative effects of unwanted and irrelevant information. Rather, retrieval is just one of many contexts in which we experience *mental fixation*, or the inability to complete some type of cognitive operation—such as remembering, solving problems, and generating creative ideas—as the result of interference from inappropriate knowledge and experience (Smith, 2003).

In a classic study, Smith and Blankenship (1991) examined the effects of mental fixation on creative problem solving using the Remote Associates Test (RAT; Mednick, 1962). In the RAT, participants are shown three cues (e.g., "manners"–"tennis"–"round") and asked to generate a target word that is associated with each of the cues (solution: "table"). The target associate can be a synonym, or part of a commonly spoken phrase, or it can share a more general semantic relation with a cue word. RAT problems can be difficult because the strongest associates to each cue often bear no relation to the other cues and would not, therefore, serve as viable solutions (e.g., "polite," "ball," and "square," respectively). In fact, Smith and Blankenship found that exposing participants to inappropriate associates prior to problem solving further impaired performance, presumably because exposure to such items caused additional fixation.

Storm and Angello (2010) reasoned that if retrieval-induced forgetting is caused by an inhibitory process that acts to overcome interference in memory, then individuals who exhibit more retrieval-induced forgetting should be better at overcoming interference in other contexts as well. They tested this hypothesis by correlating individual differences in retrieval-induced forgetting with the ability to overcome fixation on a separate RAT problem-solving task. In their experiment, half of the participants were exposed to fixating associates prior to problem solving (fixation condition), whereas half were not (baseline condition). Replicating Smith and Blankenship (1991), participants in the fixation condition solved significantly fewer problems than did participants in the baseline condition. The more novel finding was that individual differences in retrieval-induced forgetting predicted the extent to which participants suffered fixation. As shown in Figure 2, participants who exhibited the least retrieval-induced forgetting were only able to solve 47% of the problems in the fixation condition that they would have been able to solve in the baseline condition, whereas participants who exhibited the most retrieval-induced forgetting were able to solve 93% of the problems in the fixation condition that they would have been able to solve in the baseline condition. These results suggest that individual differences in retrieval-induced forgetting reflect the ability to overcome interference not only in memory retrieval but in creative problem solving as well.

If inhibition helps problem solvers overcome fixation, then associates that cause fixation, and are thus inhibited, should be forgotten as a consequence of problem solving. In recent work, Storm, Angello, and Bjork (in press) provided direct evidence of precisely this kind of problem-solving-induced forgetting. As in the study by Storm and Angello (2010), participants first studied a series of cue–response pairs. However, only a subset of the cue words from those pairs was used to form the RAT problems. Thus, some response words served as fixating associates during subsequent problem solving, whereas others did not. After problem solving, participants were given a surprise test and, in each of three experiments, the fixating associates were significantly less recallable than were the nonfixating associates, thus demonstrating problem-solving-induced forgetting (for a schematic of the paradigm, see Fig. 3).

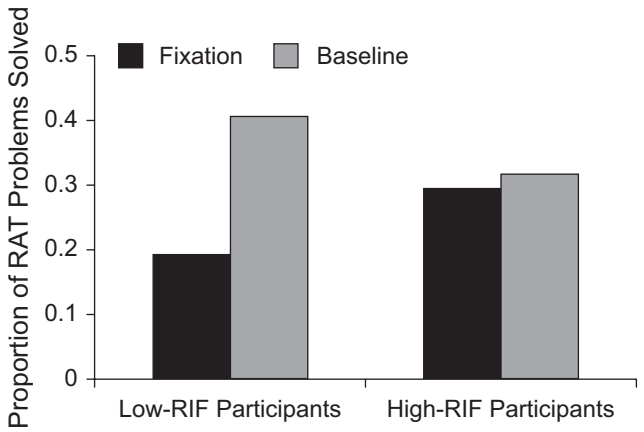

Fig. 2. RAT problem-solving performance observed by Storm and Angello (2010) as a function of individual differences in retrieval-induced forgetting. The retrieval-practice paradigm was administered first to divide participants into two groups: those demonstrating the most retrieval-induced forgetting (high-RIF, *Mean* = 16.3%) and those demonstrating the least retrieval-induced forgetting (low-RIF, *Mean* = −3.6%). All participants then attempted to solve RAT problems, either under fixation or not under fixation. Participants under fixation studied interfering cue–response pairs (e.g., "manners–polite," "tennis–ball," "round–square") prior to attempting to solve the RAT problems (e.g., "manners–tennis–round"). Interestingly, low-RIF participants performed better than high-RIF participants in the baseline condition, an observation consistent with the idea that individuals with less inhibitory control are at an advantage on tasks of creativity and insight. However, this advantage was reversed under fixation, suggesting that individuals cannot take advantage of the benefits of lacking inhibition when the costs of lacking inhibition make them more susceptible to fixation.

Problem-solving-induced forgetting and retrieval-induced forgetting appear to share a number of properties (Storm et al., in press). For example, just as retrieval-practice success is not a necessary condition for retrieval-induced forgetting (e.g., Storm et al., 2006), problem-solving success is not a necessary condition for problem-solving-induced forgetting either. In fact, problem-solving-induced forgetting occurs even when problem solving is impossible. From an inhibitory perspective this observation makes sense—fixation is experienced, and thus fixating associates need to be inhibited regardless of whether a problem-solving attempt eventually succeeds. However, problem-solving-induced forgetting can facilitate problem-solving success when problem solving is possible. In their third experiment, Storm et al. (in press) examined the correlation between problem-solving-induced forgetting and problem-solving performance on a separate set of fixated RAT problems. As expected, participants who exhibited the most problem-solving-induced forgetting solved significantly more problems than did participants who exhibited the least problem-solving-induced forgetting.

Implications for Theoretical Accounts of Forgetting

The research by Storm and colleagues provides a new and potentially important kind of evidence for inhibitory-based forgetting. Theorists in opposition to inhibition often argue

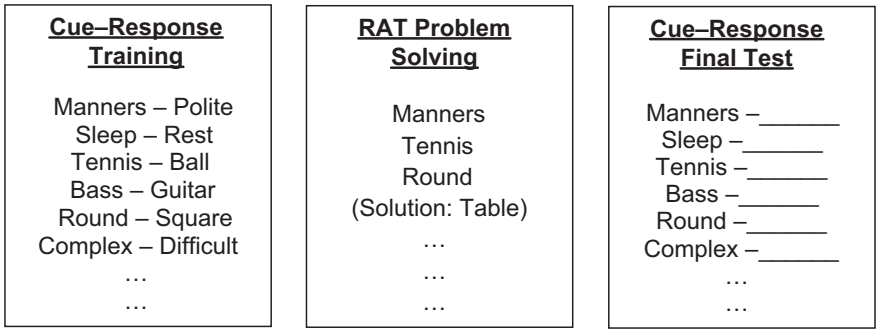

Fig. 3. Schematic of the paradigm used by Storm, Angello, and Bjork (2011) to examine problem-solving-induced forgetting. Participants first studied cue–response pairs and then attempted to solve RAT problems consisting of a subset of the cue words. Problem-solving-induced forgetting was observed such that the response words associated with cues used in RAT problem solving ("polite," "ball," "square") were recalled less well than response words associated with cues that were not used in RAT problem solving ("rest," "guitar," "difficult"). According to the inhibitory account, the response words associated with the RAT cues caused fixation during problem solving and were inhibited to help problem solvers overcome that fixation.

that phenomena like retrieval-induced forgetting can be better explained by blocking or interference. Yet if retrieval-induced forgetting was the consequence of blocking or interference, then we would expect individuals who exhibit more retrieval-induced forgetting to be more susceptible to blocking and interference than individuals who exhibit less retrieval-induced forgetting. Thus, the inhibition and interference accounts make very different predictions about how forgetting should correlate with performance on other tasks. Whereas the interference account predicts that individuals exhibiting more forgetting should be more susceptible to interference, the inhibition account predicts that individuals exhibiting more forgetting should be less susceptible to interference. The data reviewed here clearly support the inhibition account—individuals exhibiting more forgetting, as a consequence of either retrieval or problem solving, were significantly less likely to suffer problem-solving fixation than were individuals exhibiting less forgetting.

Similar evidence has been observed in other studies. For example, Aslan and Bäuml (2011) examined retrieval-induced forgetting and working-memory capacity, a construct believed to reflect the ability to control attention and to inhibit task-irrelevant information (Engle, 2002). If retrieval-induced forgetting is the consequence of interference, then individuals with greater working-memory capacity should exhibit less retrieval-induced forgetting. However, Aslan and Bäuml found that individuals with greater working-memory capacity exhibited more retrieval-induced forgetting than did individuals with less working-memory capacity. In another example, Storm and White (2010) examined retrieval-induced forgetting in attention-deficit/hyperactivity disorder (ADHD). A critical impairment in ADHD is poor inhibitory control, which makes it difficult to avoid interference or distraction from competing information. Once again, if retrieval-induced forgetting is caused by interference, then individuals with ADHD should, if anything, be more likely to exhibit retrieval-induced forgetting. Yet, as predicted by the inhibitory account, individuals with ADHD exhibited significantly less retrieval-induced forgetting than did individuals without ADHD.

It is important to note that not all retrieval-induced forgetting is caused by inhibition. For example, when researchers employ a category-cued final test (e.g., "fruit?"), participants are free to recall exemplars in any order they wish. As a consequence, participants generally recall the practiced items first, causing the nonpracticed items to be less recalled due to output interference. This is problematic because individuals with impaired inhibition are more likely to suffer output interference, thus making them more likely to exhibit interference-based, as opposed to inhibitory-based, retrieval-induced forgetting (see Anderson & Levy, 2007). The pattern of data observed by Storm and White (2010) supports this possibility. Whereas individuals with ADHD failed to exhibit any retrieval-induced forgetting on a test that controlled for output interference (e.g., "fruit-l_____"), those same individuals exhibited normal levels of retrieval-induced forgetting on a test that did not control for output interference (e.g., "fruit?"). Thus, although examining individual differences in retrieval-induced forgetting provides a promising avenue for future research, researchers must be careful to employ designs that are specifically sensitive to inhibitory-based forgetting.

Concluding Comment

The ability to retrieve and generate information that is wanted, relevant, and appropriate is made possible by the ability to inhibit, and thus forget, information that is unwanted, irrelevant, and inappropriate. In the context of memory, inhibition facilitates the retrieval of target items in the face of interference from nontarget items. In the context of problem solving, inhibition facilitates the generation of viable solutions in the face of interference from nonviable solutions. Although more research is needed, it is possible that inhibition has the

capacity to facilitate any act of remembering, thinking, or problem solving that relies on the ability to overcome the fixating consequences of interfering information. The ability to forget, at least under certain conditions, appears to reflect the adaptive functioning of memory, not its failure. As frustrating as forgetting might seem, we are far better with it than we would be without it.

Recommended Readings

Anderson, M.C. (2003). (See References). A comprehensive overview of retrieval-induced forgetting and theoretical issues related to inhibitory processes in memory.

Gorfein, D.S., & MacLeod, C.M. (Eds.). (2007). *Inhibition in cognition.* Washington, DC: American Psychological Association. A highly accessible collection of chapters addressing the concept of inhibition and how it has developed over recent years.

Smith, S.M. (2003). (See References). A clearly written, user-friendly, and relatively comprehensive review for readers who wish to know more about mental fixation and the constraining effects of initial ideas.

Storm, B.C. (2011). (See References). A paper discussing the relation between retrieval-induced forgetting and overcoming competition in more detail than the current article.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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