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Retrieval-Induced Forgetting and Context

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Abstract

Retrieving information can result in the forgetting of related information, a phenomenon referred to as *retrieval-induced forgetting* (RIF). To date, the dominant explanation of RIF has been an inhibition account, which emphasizes long-term suppression of interfering memories. As one alternative, some have advocated for a strength-based interference account, which emphasizes the role of strengthening associations. More recently, we have proposed a context account, which emphasizes the role of context change and context reinstatement. In this article, we outline these three accounts of RIF and demonstrate that there is substantial evidence that uniquely supports our context account.

Keywords

memory, retrieval-induced forgetting, inhibition, context

In recent years, the literature on human memory has seen a surge of research on the positive and negative effects of retrieving information from memory. This work has revealed that retrieval is a highly efficient way to improve subsequent memory for material—even more efficient than simply rereading that material. Despite this benefit, retrieval also has a "dark side": Retrieving information can result in the forgetting of related information. For example, retrieval of *orange* can result in difficulty remembering *banana* at a later time because these two exemplars share membership in the category *FRUIT*. This phenomenon, now widely known as *retrieval-induced forgetting* (RIF; Anderson, Bjork, & Bjork, 1994), has been well documented and is the focus of much contemporary research.

Study of RIF typically involves a memory task consisting of three phases. First, participants complete a study phase in which they are shown a number of category-exemplar word pairs (e.g., *FRUIT–orange, FRUIT–banana, INSECT–wasp*). Next, during a retrieval-practice phase, they are prompted by a category name and word stem (e.g., *FRUIT–or?*) to retrieve some of the exemplars from some of the categories (e.g., retrieval of *orange* but not of *banana* or *wasp*). This phase results in three types of exemplars: practiced exemplars (*orange*; denoted RP+); unpracticed, categorically related exemplars (*banana*; denoted RP–); and exemplars from unpracticed categories (*wasp*; denoted NRP). Finally, participants complete a test phase during which they attempt category-cued recall of all studied exemplars. Unsurprisingly, RP+ exemplars (*orange*) are recalled best because they were practiced. The surprising result is that RP– exemplars (*banana*) are recalled more poorly than NRP exemplars (*wasp*). Hence, retrieving some information actually induces forgetting of related information.

For the past two decades, researchers have been intrigued by RIF and have sought to identify the cognitive mechanisms underlying this type of forgetting. At present, there are three competing accounts of RIF, each highlighting a different potential mechanism: inhibition, strength-based interference, or context cuing. In this article, we first briefly outline these accounts and then consider their success in explaining RIF.

Inhibition

The most widely accepted interpretation of RIF is that it is the product of inhibition (Anderson, 2003; Anderson & Hanslmayr, 2014; Anderson & Levy, 2009; Storm & Levy, 2012). According to the inhibition account, RIF occurs because, during the retrieval-practice phase, the category name (e.g., *FRUIT*) activates strongly associated exemplars (*orange* and *banana*), which results in substantial

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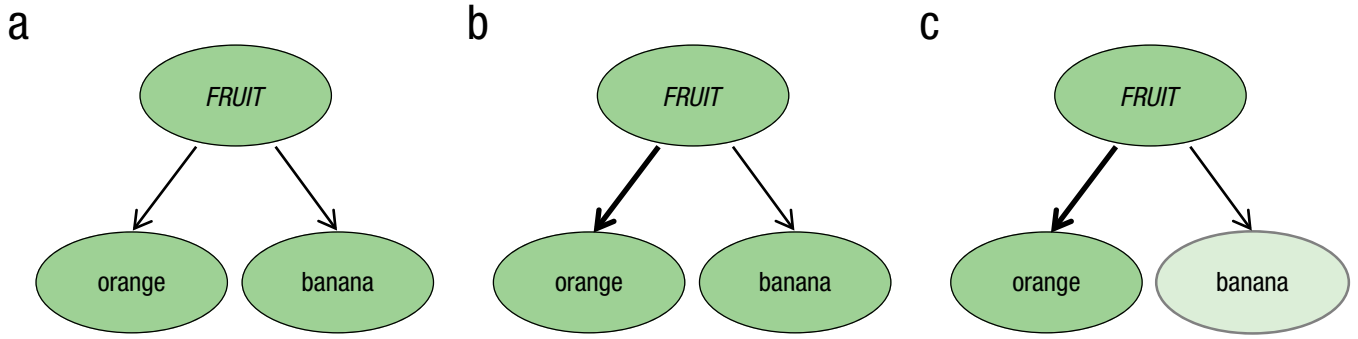

Fig. 1. A visual depiction of categories, exemplars, and their associations in the retrieval-induced-forgetting paradigm. Panel (a) reflects category-exemplar associations after the study phase. Panel (b) reflects the strengthened association of the practiced exemplar with its category that follows retrieval practice, as predicted by the strength-based interference account. Panel (c) reflects the inhibited representation of the unpracticed, categorically related exemplar that follows retrieval practice, as predicted by the inhibition account.

interference among them. To reduce this interference and allow for the successful retrieval of the target exemplar (*orange*), the memory representations of competing exemplars (*banana*) are inhibited. This inhibition is enduring, such that, on a later test, inhibited exemplars are difficult to recall. On the other hand, because the exemplars in NRP categories did not undergo retrieval practice, there is no interference among these exemplars and hence no inhibition of any of them. Thus, on the final test, RP– exemplars are more poorly recalled than NRP exemplars because the former have been inhibited.

Over the past 20 years, the inhibition account has dominated the RIF literature and has received support from a great deal of research (Murayama, Miyatsu, Buchli, & Storm, 2014). As a result, the phenomenon of *retrieval-induced forgetting* has become nearly synonymous with the mechanism of *inhibition*. Consequently, RIF has come to be accepted as a measure of inhibitory ability, resulting in such bold claims as "Inhibitory processes in memory are impaired in schizophrenia" (Soriano, Jiménez, Román, & Bajo, 2009, p. 661).

Strength-Based Interference

Despite the widespread popularity of inhibition theory, a strength-based interference account of RIF is not without merit (Raaijmakers & Jakab, 2013a, 2013b; Verde, 2013). This account posits that retrieval strengthens the association between practiced category-exemplar pairs (compare Fig. 1a and Fig. 1b) and that RIF ensues because the presentation of the category cue on the final test results in activation of—and interference from—the strengthened RP+ exemplars. Thus, RP– exemplars are forgotten not because they were inhibited (Fig. 1c) but because associations between the cues and the practiced exemplars were strengthened, which leads the stronger RP+ exemplars to interfere with recall of the weaker RP– exemplars.

Although rejected early on (Anderson, 2003), the strength-based interference account has found support in recent evidence. For example, Raaijmakers and Jakab (2012) had participants retrieve the category rather than the exemplar (e.g., *FR?–orange*). Critically, this type of retrieval should not produce competition between exemplars because exemplars are not being retrieved. Accordingly, the inhibition account predicts no RIF because there is no retrieval competition and hence no need to inhibit competing exemplars. On the other hand, the strength-based interference account predicts RIF because the category-exemplar association is being strengthened, which should produce interference for the RP– exemplars. Indeed, the authors did observe RIF following category retrieval, which uniquely supported the strength-based account (see also Jonker & MacLeod, 2012).

Context

Most recently, we introduced a new account of RIF, emphasizing the role of internal context shifts during memory tasks (Jonker, Seli, & MacLeod, 2013). This context account derives from models implicating a pivotal role for context in memory (e.g., Mensink & Raaijmakers, 1988; Polyn, Norman, & Kahana, 2009) and, in particular, a body of research demonstrating that retrieval can result in internal context shifts (e.g., Divis & Benjamin, 2014; Jang & Huber, 2008; Sahakyan & Kelley, 2002), which can in turn have a significant effect on memory. On the basis of these findings, we have postulated that two conditions underlie RIF. First, a context shift occurs between study and retrieval practice, which results in one context containing all exemplars (i.e., study) and another context containing only practiced exemplars (i.e., retrieval practice). Second, the category names presented as cues during the final test lead people to reinstate the retrieval-practice context for practiced categories and the study context for unpracticed categories.

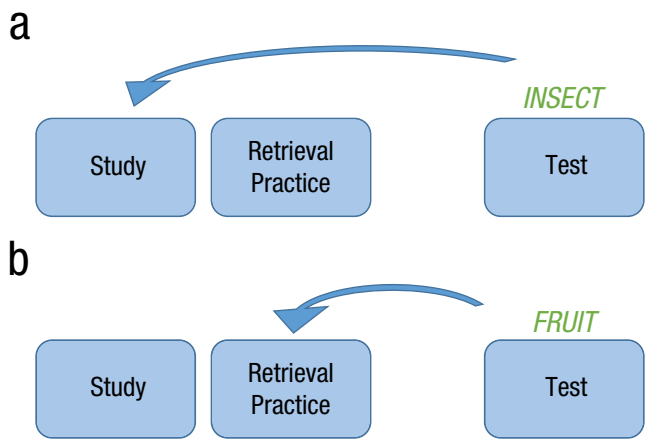

Fig. 2. A visual depiction of the use of context in the standard retrieval-induced-forgetting paradigm according to our context-change account. Panel (a) reflects context reinstatement of the study phase upon presentation of a category name from an unpracticed category. Panel (b) reflects context reinstatement of the retrieval-practice phase upon presentation of a category name from a practiced category.

These two conditions explain RIF in the following way: While being tested on NRP exemplars (*INSECT*), the only context that is a candidate for reinstatement is the study context, because NRP exemplars appeared only during the study phase. Thus, during the test, participants reinstate that context to access the NRP exemplars, which consequently benefit from context reinstatement (Fig. 2a). For a category with practiced exemplars (*FRUIT*), however, both the study and retrieval-practice contexts are candidates for reinstatement because exemplars from the practiced category were presented both during study and during retrieval practice. Thus, participants reinstate the retrieval-practice context—because it is more recent and/or because it gained substantial strengthening through retrieval—which results in no context-reinstatement benefit for RP– exemplars because they were presented only in the study context (Fig. 2b). Therefore, our account postulates that RIF occurs because NRP exemplars (*wasp*) benefit from context reinstatement whereas RP– exemplars (*banana*) do not. Critically, our account does not require inhibition or item-based interference to explain RIF.

To test our context account of RIF, we manipulated context on the final test using short video clips of everyday contexts (Smith & Manzano, 2010). For example, in the first phase, during study of category-exemplar pairs from the *FRUIT* category, participants also saw a video of a park, and during study of *INSECT* exemplars, they saw a video of an elevator (see Fig. 3 for an illustration of our procedure). During the retrieval-practice phase, practiced exemplars were paired with a novel video; for example, *FRUIT* items were presented with a video of a windmill. Importantly, this procedure allowed us to manipulate the context that participants reinstated during the final test. Specifically, during the test, one group was provided with the retrieval-practice video (of, e.g., a windmill) to reinstate the retrieval-practice context (a process that we propose occurs naturally in the standard paradigm); this should result in RIF because the RP– exemplars should not benefit from context reinstatement and should therefore be recalled less well than the NRP exemplars, which always benefit from context reinstatement. The second group was provided with the study video (of, e.g., a park) to reinstate the study context, which, importantly, should result in a context reinstatement benefit for the RP– exemplars. Under these conditions, no RIF should be observed because both the NRP and RP– exemplars

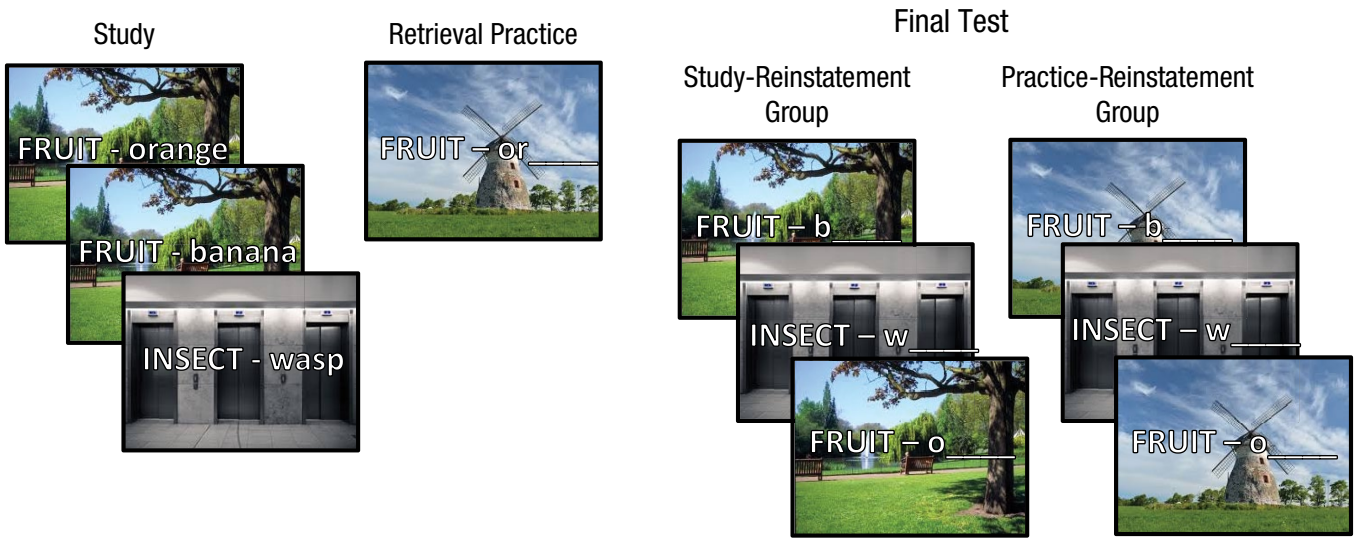

Fig. 3. A visual depiction of the procedure of Experiment 3 in Jonker, Seli, and MacLeod (2013).

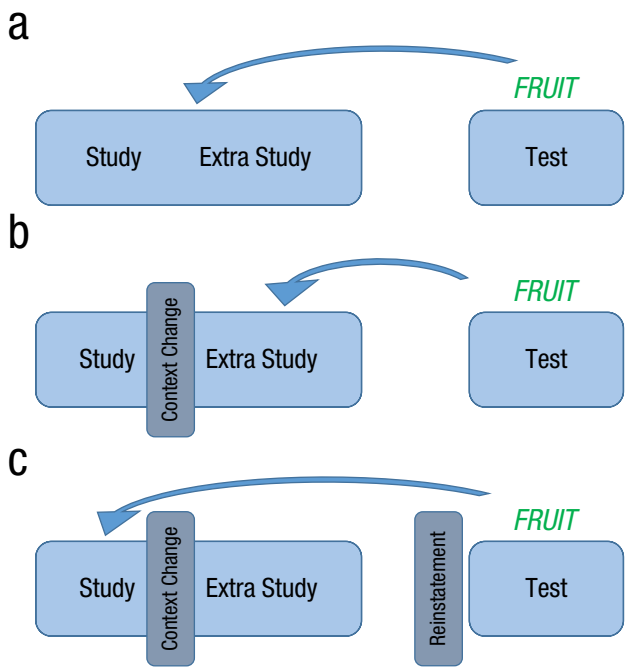

Fig. 4. A visual depiction of the use of context in the extra-study variant of the retrieval-induced-forgetting paradigm according to our context-change account. Panel (a) depicts the study and extra-study phases as a single context. Panel (b) reflects context reinstatement of the retrieval-practice phase after context change has been induced. Panel (c) reflects context reinstatement of the study phase after context change and a reinstatement task.

should benefit from context reinstatement and therefore be recalled equally well. Our results were consistent with the foregoing predictions and thus provided support for our account.

Further support for our context account came from a series of experiments examining the extra-study variant of the RIF paradigm. In this variant, all details are identical to the standard RIF paradigm with one exception: Rather than performing retrieval practice in the second phase, participants simply restudy some of the exemplars from some of the categories. The common finding observed with this variant is that the restudied exemplars (RP+) are better remembered but that there is no RIF (Anderson & Bell, 2001). As noted above, a critical prediction of our context account is that RIF occurs only when there is a context change between the study and practice phases. In the case of the standard RIF paradigm, a context shift occurs as a natural consequence of retrieval practice (Sahakyan & Hendricks, 2012). However, because there is no retrieval practice in the extra-study variant, we postulate that the study and extra-study phases are represented as a single context (Fig. 4a). Thus, reinstating this single context on the final test should result in context-reinstatement benefits for both NRP and RP− exemplars, which explains the absence of RIF.

A clear prediction follows directly from our account: If the study phase were made contextually distinct from the extra-study phase, then RIF should occur—despite the absence of retrieval practice—because for practiced categories (*FRUIT*), participants should reinstate the extra-study context during the final test, resulting in no context-reinstatement benefit for RP− exemplars. To test this prediction, we induced a context change between study and extra study (Fig. 4b), which resulted in RIF, as uniquely predicted by our context account (Jonker et al., 2013). In a second manipulation, we induced a context change between study and extra study but then guided participants to reinstate the study context rather than the extra-study context (Fig. 4c). Under these conditions, RP− exemplars—like NRP exemplars—should benefit from context reinstatement despite not being part of the more recent extra-study context, and RIF should not occur. The prediction of the context account was again supported.

Our experiments provide unique support for our context account and cannot be explained by the other accounts of RIF. The inhibition account has no explanation for why reinstating the study context via context videos did not result in RIF. In addition to our context-based results, there is a growing body of literature in which we and others have tested and challenged the key assumptions of inhibition theory (e.g., Camp, Pecher, Schmidt, & Zeelenberg, 2009; Jakab & Raaijmakers, 2009; Jonker & MacLeod, 2012; Jonker, Seli, & MacLeod, 2012; Raaijmakers & Jakab, 2012, 2013b; Verde, 2013), highlighting the fact that, despite its widespread acceptance, inhibition theory does not account for a number of fundamental findings in the extant literature.

There have been a number of tests of the fundamental assumption of the *cue independence* of inhibition (see, e.g., Anderson, 2003). According to the inhibition account, suppression is applied to the competing representations (*banana*) themselves, not to the cue-target association (Fig. 1c), implying that these inhibited representations should be difficult to access on the test even when a novel, unstudied cue is used to probe memory. To test the cue independence of RIF, we presented participants with exemplars that could be subcategorized within their category (Jonker et al., 2012). For example, within the category *BIRDS*, some exemplars were birds of prey (e.g., *eagle*) whereas others were pets (e.g., *canary*). Participants performed retrieval practice on all exemplars from one subcategory. This is a subtle difference, one that participants did not notice (see also Gardiner, Craik, & Birtwistle, 1972). During the final test, some participants were shown the subcategory information whereas others were not. The latter condition reflects the standard RIF procedure. According to the cue-independence assumption of the inhibition account, the cues provided should not influence the occurrence of RIF because the exemplar itself is

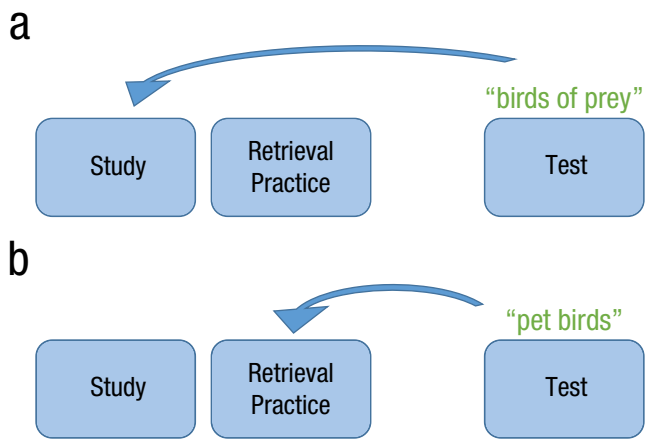

Fig. 5. A visual depiction of the use of context in experiments by Jonker, Seli, and MacLeod (2012). Panel (a) reflects context reinstatement following the presentation of subcategory information unique to the unpracticed, categorically related exemplars. Panel (b) reflects context reinstatement following the presentation of subcategory information unique to the practiced exemplars.

inhibited and inaccessible irrespective of the cue. However, when we provided the subcategory information at the time of the final test, RIF no longer occurred. Although our results cannot be explained by the inhibition account, they are well explained by our context account: When participants were provided with subcategory information, they could use each cue to access the relevant context (see Fig. 5). For example, if RP– exemplars were all birds of prey, then providing the birds-of-prey subcategory information would lead to reinstatement of the study context, causing a context-reinstatement benefit for the RP– exemplars and therefore no RIF.

Strength-based interference accounts also have difficulty explaining our context effects. Specifically, strength-based models focus on the strengthening of the association between category and RP+ exemplars, which then results in interference with recall of the RP– exemplars and hence forgetting. But these accounts do not provide an explanation for why reinstating the study context should improve recall of the RP– exemplars. Notwithstanding these limitations, it does seem likely that strength-based interference plays an important role in RIF. For example, diluting the potency of a cue by increasing the number of exemplars results in lower recall of the exemplars and an RIF-like effect (e.g., Verde, 2013, Experiment 6). Thus, a well-rounded account of RIF will likely include roles for both context and cue-target associative strength. In fact, although we have treated the three accounts of RIF as mutually exclusive in the present article, it is possible—even likely—that more than one mechanism underlies RIF. Therefore, we encourage researchers to consider the interplay between various mechanisms in future work on RIF.

Summary

In this article, we outlined the three main accounts of RIF. We then described our recent research demonstrating that reinstating the study context for practiced exemplars abolishes RIF, and that RIF can be produced even under conditions where inhibition and strength-based accounts predict none. In presenting compelling evidence for the role of context reinstatement in RIF, our work demonstrates numerous circumstances that the dominant inhibition account cannot explain. We therefore conclude (a) that employing the RIF paradigm as a measure of "inhibitory abilities" of special populations is certainly premature and (b) that future research should carefully consider the role of context in RIF. Indeed, memory is profoundly contextual, and it is thus not surprising that RIF, like many other aspects of memory, is sensitive to context and context change.

Recommended Reading

Anderson, M. C. (2003). (See References). A theoretical article detailing the fundamental assumptions of the inhibition account.

Jonker, T. R., Seli, P., & MacLeod, C. M. (2013). (See References). A theoretical article setting out our context account and reviewing the majority of the RIF literature as it applies to that account.

Murayama, K., Miyatsu, T., Buchli, D., & Storm, B. C. (2014). (See References). A meta-analytic review of RIF, focusing on the data relevant to the inhibition account.

Raaijmakers, J. G. W., & Jakab, E. (2013a). (See References). An article that reviews tests of the inhibition account and argues in support of the strength-based interference account.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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