Is forgetting caused by inhibition?

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Abstract

A well-known finding in memory research is the forgetting effect that occurs due to practicing some item A on the recall of a related item B. The traditional explanation for such interference effects is based on the notion of competition. According to the inhibition theory of forgetting, however, such forgetting is due to an inhibitory control process that operates whenever the retrieval of specific target information is hindered by competition from related information. The suppression of the related information is a longer-lasting phenomenon that may show up on later testing. We report several experiments that were carried out to test two fundamental assumptions of the inhibition theory, the interference dependence and retrieval specificity assumptions. The results of these experiments do not support the predictions of the inhibition theory. Instead, the results are more compatible with the standard account that attributes the forgetting to competition at the time of the later testing.

Keywords: inhibition, interference, forgetting

A standard finding in memory research is the forgetting effect that occurs due to practicing some item *A* on the recall of a related item *B*. The standard explanation for such interference effects that dates back to at least the 1930s (see McGeoch, 1932) is based on the notion of competition. During the past fifteen years, a number of researchers (Anderson, Bjork, & Bjork, 1994; Anderson, 2003) have proposed an alternative explanation based on the idea that such forgetting is due to an adaptive control mechanism that operates whenever a target memory trace *A* needs to be retrieved in the presence of a strong competitor *B*. That is, while the subject is trying to retrieve a given item *A*, a (stronger) item *B* may be competing and in order to resolve this competition, the *B* item has to be suppressed. The crucial assumption of the inhibition theory is that such repeated suppression of *B* leads to a longer-lasting inhibition of the memory trace of *B*. Inhibition proponents have claimed this inhibition hypothesis provides a superior account of interference-based forgetting effects compared to traditional theories based on competition (e.g., the SAM model, Raaijmakers & Shiffrin, 1981; Mensink & Raaijmakers, 1988).

Although the inhibition theory has been applied to a number of other experimental paradigms (directed forgetting, part-list cuing), we will restrict the discussion in this paper to the *retrieval induced forgetting (RIF)* paradigm, introduced by Anderson, Bjork and Bjork (1994) and used most frequently in research on inhibition. Figure 1 gives a brief description of this paradigm. What is important is that in this paradigm, there is a decrease in recall for nonpracticed items from practiced categories (the RP- items) compared to nonpracticed items from nonpracticed categories (NRP items). This difference in recall probability between the NRP and the RP- items is termed the *RIF effect*. According to the inhibition theory, the RIF effect is due to the fact that the RP- items were activated during the retrieval practice phase of the experiment and in order to resolve this conflict the RP- items had to be suppressed. It is this suppression that is responsible for the lower recall of the RP- items, not the increased competition by the (now stronger) RP+ items (as assumed by a competition account).

The inhibition account of retrieval induced forgetting makes a number of predictions that differentiate it from the competition account (see Anderson, 2003). In this article, we will focus on two of these:

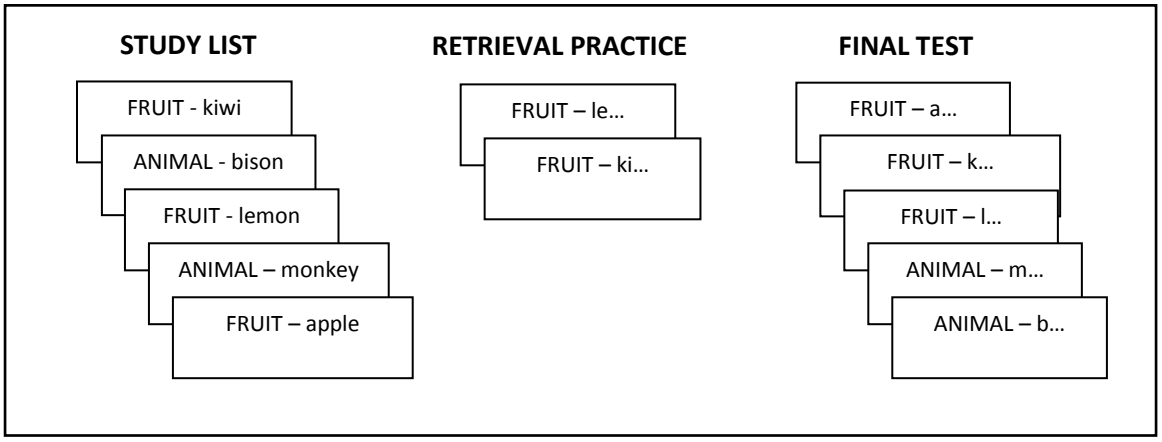

Figure 1:
Standard design of a retrieval induced forgetting experiment. In the initial study phase, a series of category-exemplar pairs is studied. Next, some of the items from some of the categories (in this case FRUIT) are given additional retrieval practice trials in which the category name as well as the initial two letters from the target item are presented as cues. In the final test phase, all of the category-exemplar pairs are tested by presenting the category name and the first letter as cues. In this example, FRUIT is a practiced category and *lemon* and *kiwi* are practiced items (RP+ items). *Apple* is a nonpracticed item from a practiced category (a RP- item). ANIMAL is a nonpracticed category of which none of the items are practiced (NRP items). According to a competition account of RIF, the observed decrease in recall of the RP- item, is due to the stronger association of the category name to the RP+ items. According to the inhibition account, it is due to the fact that the memory trace of the RP- item has become weaker due to suppression of *apple* during the retrieval practice phase .

(a) *Interference dependence*: RIF effects depend on the extent to which there is interference from RP- items during the practice of the RP+ items: stronger items should be inhibited more than weaker items since weaker items are less interfering.
(b) *Retrieval specificity*: RIF effects are specific to those tasks that involve the active retrieval of the RP+ items in a way that makes it possible for the RP- items to hinder the retrieval of the target RP+ item. Practice tasks that do not involve the retrieval of the memory trace of the RP+ item, will show no RIF effects.

INTERFERENCE DEPENDENCE

In order to test this prediction the amount of forgetting is compared for RP- items that are either weak or strong. The initial experiments were carried out by Anderson, Bjork and Bjork (1994). They compared categories that consisted of either all weak or all strong exemplars (strong meaning that the item has a high probability of being generated in response to the category name) and indeed observed more forgetting for the strong RP- items. However, in a replication study, Williams and Zacks (2001) observed no difference in the amount of RIF between weak and strong RP- exemplars.

In our research (Jakab & Raaijmakers, 2009) we used two different methods to create weak and strong items. In the first two experiments, we took advantage of the fact that in category cued recall there is a strong within-category primacy effect: the items presented first from each category are recalled much better than the later items from that category. As a result, the primacy items should be more likely to be activated by the category cue during the retrieval practice and hence should be more likely to be

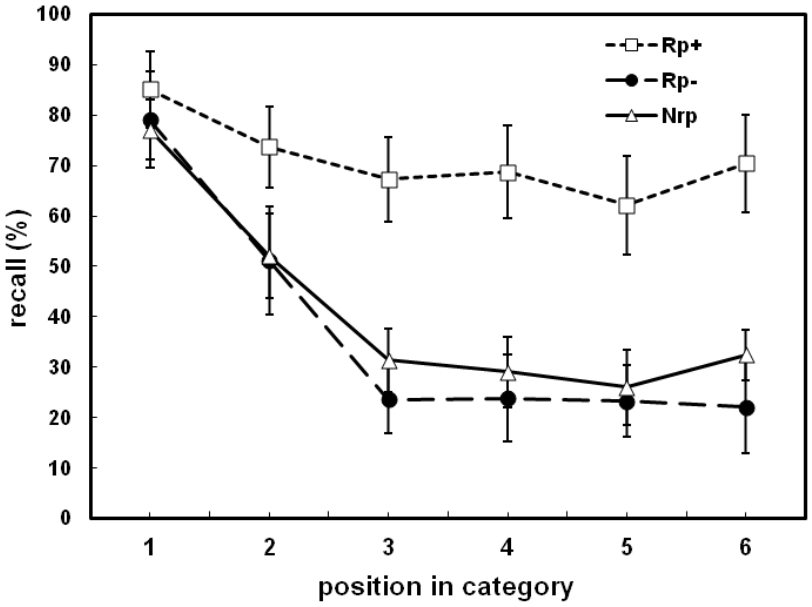

Figure 2:
Mean recall for the RP+, RP- and NRP items as a function of the within-category serial position on the original study list. Reprinted from Jakab and Raaijmakers (2009).

suppressed. The results (see Figure 2; data from Exp 1 of Jakab & Raaijmakers, 2009) clearly showed that this was not the case: the stronger (primacy) items did not show a larger RIF effect than the weaker items.

A second manipulation of strength was to present some of the RP- items twice and some once during the initial study phase. The RP+ items were always presented once. According to the interference dependence assumption, the twice presented RP- items should be more likely to interfere and hence should be inhibited more. As can be seen in Figure 3, the results again failed to support this prediction: there was no difference in the size of the RIF effect for items presented once or twice, despite the fact that the strength manipulation was clearly effective.

Other evidence also appears to contradict the interference dependence assumption. For example, both Perfect et al. (2004) and Verde (2012) pointed out that many experiments have shown sizable RIF effects despite the fact that the items that were used should have been considered weak (e.g. episodically defined word pairs). Thus, the results regarding the interference dependence assumption are inconsistent, with the initial experiments of Anderson et al. (1994) supporting it, while later experiments do not. Claims that the discrepant results obtained by Williams and Zacks (2001) and Jakab and Raaijmakers (2009) might be due to lack of control for output interference that would have led to an increased RIF effect for the weak items (see Storm, 2010; Storm & Levy, 2012) are unlikely to be true since such output interference effects should equally affect the strong items, if not more so (see Raaijmakers & Jakab, 2013).

Inhibition theorists (see Anderson and Levy, 2010, p. 120-122), have suggested that strong competitors may not show larger RIF effects because of what they termed the *Demand/Success Tradeoff* problem. That is, as the demand for inhibitory control increases, the likelihood of its success decreases. Hence, the attempt at inhibition might not succeed and the RP- items might even become stronger than they would have been without the retrieval practice on the RP+ items. Of course, such an assumption makes it difficult to test the interference dependence assumption.

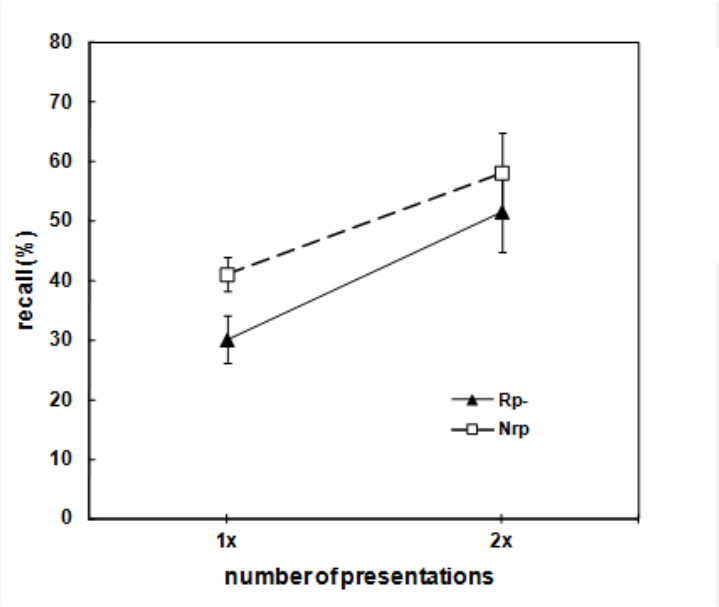

Figure 3:
Mean recall for the RP- and NRP items as a function of the number of presentations on the original study list (Exp 3 in Jakab and Raaijmakers(2009) . Reprinted from Jakab and Raaijmakers (2009).

All in all, the evidence for the interference dependence assumption appears to be rather weak. Most of the evidence seems to be consistent with competition-based accounts of RIF that predict about equal RIF effects for both strong and for weak items (see Jakab & Raaijmakers, 2009).

RETRIEVAL SPECIFICITY

The inhibition explanation of forgetting is based on the assumption that during the retrieval practice of the RP+ items, the RP- items have to be suppressed in order to resolve the competition from the RP- items. According to this account, it is essential that the RP+ items have to be actively retrieved; otherwise there would not be any need for suppressing the RP- items. Other ways of strengthening the RP+ items (e.g. by repeated study of those pairs) that do not involve active retrieval, would not lead to a RIF effect. This is called the retrieval specificity assumption. Competition-based accounts on the other hand assume that the RIF effect is due to the competition by the strengthened RP+ items on the final test of the RP- items. Hence, such accounts would predict that it does not matter how the RP+ items have been strengthened, only that they have been strengthened.

Several experiments have been performed to test the retrieval specificity assumption by comparing the standard retrieval practice to a type of practice that does not involve competitive retrieval, that is, a type of practice where the RP- items are assumed not to compete during the practice of the RP+ items. The initial experiment of this type was carried out by Anderson, Bjork and Bjork (2000). They compared the standard competitive retrieval practice condition with a condition in which during the retrieval practice phase, the participants had to generate the category name in response to the item (rather than the item in response to the category name). For example, they had to respond "fruit" to the cue "FR… - kiwi". Since it is assumed that in this type of practice there is no competition from the other category exemplars, it is termed "non-competitive retrieval practice".

Anderson et al. (2000) observed a normal RIF effect for the standard, competitive, retrieval practice, but no RIF effect at all for the non-competitive retrieval practice, despite the fact that the performance on the RP+ items was virtually identical in both conditions. Similar results have been obtained in a number of experiments in which the non-competitive condition involved additional study trials on the RP+ items. On first sight, these results appear to be inconsistent with a competition-based account of RIF.

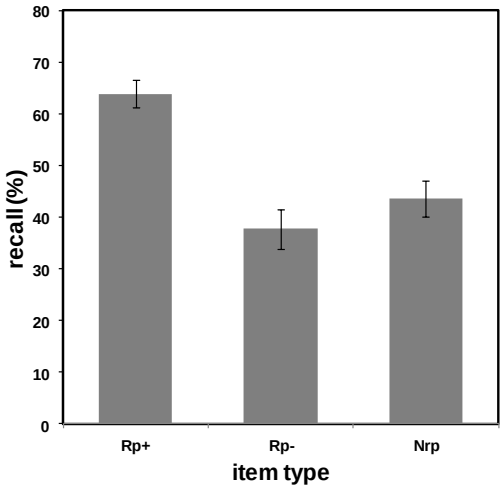

Figure 4
Mean recall for the RP+, RP- and NRP items following noncompetitive retrieval practice. . In this experiment the nnoncompetitive practice was made more difficult by using categories based on properties (e.g. "round things") and by using low frequency exemplars. Reprinted from Raaijmakers and Jakab (2012).

Raaijmakers and Jakab (2012) demonstrated however that the implicit assumption that equal RP+ recall implies equal amounts of learning or equal strengths, is incorrect.

In order to see why this would be the case, it is important to note that in these experiments no feedback is given after competitive retrieval practice. As a result, if a participant is not able to recall the RP+ item on the first retrieval practice trial, it is unlikely that the item will be recalled on the next retrieval practice trials. Similarly, if the item is recalled, it will most likely be recalled again. Since the items that are recalled will already be of higher strength than the nonrecalled items and since only those recalled items gain additional strength due to being retrieved, such a procedure leads to a distribution in which some of the items are of very low strength (the nonrecalled RP+ items) and some have a much higher strength. Most importantly, since the recalled RP+ items are by definition already strong enough to be recalled, any increase in their strength will not be reflected in the probability of recall although it will show up after a delay (see Karpicke & Roediger, 2008; Kornell, Bjork & Garcia, 2011). Hence, although the probabilities of recall may be equal for the retrieval practice and additional study conditions, this does not imply that the strengths for the RP+ items are equal. Since it is the strength of the RP+ items that determines how interfering they are on the final test for the RP- items, it is quite possible for a competition-based account to predict a much larger RIF effect for the retrieval practice condition compared to the extra study trials condition. Raaijmakers and Jakab (2012) presented a simulation based on the SAM model (Raaijmakers & Shiffrin, 1981) that demonstrated that such an account of the Anderson et al. (2000) results is indeed possible, if not likely.

We (Raaijmakers & Jakab, 2012) took a different approach to testing the retrieval specificity assumption. Rather than comparing competitive and noncompetitive retrieval practice conditions, we modified the noncompetitive condition in such a way as to make the task more difficult (and hence more challenging). We assumed that one of the reasons why Anderson et al. (2000) had failed to find a RIF effect in their noncompetitive condition was that their task was too easy and might have strengthened the item representation more than the category-item association. According to a noninhibitory model such a SAM, it is these category-item associations that are responsible for whether or not a RIF effect will be observed. Figure 4 shows the results of this experiment. As expected, the RP+ items were recalled better than the NRP control items. More importantly, there was a significant RIF effect (the difference between the RP- and NRP conditions) despite the fact that a noncompetitive retrieval practice procedure was used. Similar results were obtained in a recent series of experiments reported by Jonker and MacLeod

(2012). They showed that in a task that did not involve competitive retrieval practice, the occurrence of a RIF effect depended on whether or not a category retrieval task was included during the retrieval practice phase. Hence, these experiments support the assumption that the lack of a RIF effect observed by Anderson et al. (2000) may have been due to a lack of strengthening of the category-item associations.

In conclusion, noncompetitive retrieval practice can lead to a RIF effect provided that enough new information is stored, especially information that binds the practiced category-exemplar pair.

CONCLUDING REMARKS

The hypothesis that the RIF effect might be due not to competition as is traditionally assumed but to an inhibitory control process that suppresses competing information to enable retrieval of the target information, has had a major influence on recent research on forgetting. However, the inhibition hypothesis is still highly controversial and the empirical evidence is not consistent (see Verde, 2012, for a critical review). In this paper we focused on the evidence for the interference dependence and the retrieval specificity assumptions. The results of a number of recent experiments do not support the inhibition hypothesis. Of course, forgetting might be a dual-process phenomenon with both competition as well as inhibition contributing (similar to the traditional two-factor account, see Postman, 1961). However, we are not convinced that such a two-process model is really necessary and should be preferred over a pure competition-based account. What is clear, however, is that a pure inhibition-based account will not be able to handle these results.

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Recommended readings

(1) Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language, 49,* 415-445.

A detailed and comprehensive (although somewhat biased) review of the inhibition theory that tries to answer several criticisms raised.

(2) Anderson, M. C., & Levy, B. J. (2010). On the relation between inhibition and interference in cognition. In A. Benjamin (Ed.), *Successful remembering and successful forgetting: A Festschrift in honor of Robert A. Bjork*. (pp. 107-132). London: Psychology Press.

A more specialized review of the inhibition theory that focuses on possible reasons for failing to find inhibition.

(3) Bäuml, K.-H. (2008). Inhibitory processes. In H. L. Roediger, III (Ed.), *Cognitive psychology of memory. Vol. 2 of Learning and memory: A comprehensive reference, 4 vols.* (J.Byrne Editor), pp. 195-220. Oxford: Elsevier.

A comprehensive and unbiased review of the role of inhibition in a number of experimental paradigms.

(4) Raaijmakers, J. G. W., & Jakab, E. (2013). Rethinking inhibition: On the problematic status of the inhibition theory for forgetting. *Journal of Memory and Language,* http://dx.doi.org/10.1016/j.jml.2012.10.002.

A comprehensive critical (and somewhat biased) review of the evidence in favor of the inhibition account.

(5) Verde, M. F. (2012). Retrieval-induced forgetting and inhibition: A critical review. In B. H. Ross (Ed.), *Psychology of learning and motivation, vol. 56.* (Pp.47-80). USA: Academic Press.

A critical but unbiased review of the experimental evidence for inhibition.