Mem Cogn (2012) 40:861–873
DOI 10.3758/s13421-012-0206-4

List-method directed forgetting: The forget cue improves both encoding and retrieval of postcue information

Bernhard Pastötter · Oliver Kliegl · Karl-Heinz T. Bäuml

Published online: 17 May 2012

Abstract In list-method directed forgetting, people are cued to forget a previously studied item list and to learn a new list instead. Such cuing typically leads to forgetting of the first list and to memory enhancement of the second, referred to as *list 1 forgetting* and *list 2 enhancement*. In the present study, two experiments are reported that examined influences of items' serial learning position in a list and the two lists' output order on list-method directed forgetting. The results show that list output order influences list 2 enhancement but not list 1 forgetting. The enhancement was higher when list 2 was recalled first than when list 1 was recalled first and, in both cases, was higher for early list 2 items than for middle and late list 2 items. In contrast, the forgetting was equally present for all list 1 items and did not depend on the two lists' output order. The findings suggest that two separate factors can contribute to list 2 enhancement: one (encoding) factor that is restricted to early list 2 items and does not depend on list output order, and another (retrieval) factor that pertains to all list 2 items and varies with the two lists' output order. A new two-mechanism account of directed forgetting is suggested that reconciles previous (encoding *or* retrieval) views on list 2 enhancement.

Keywords Directed forgetting · List output order · Serial list position · Reset of encoding · Interference

People's memory for newly encoded information can be enhanced by cuing them to forget related older information. Corresponding evidence arises from list-method directed forgetting. In this paradigm, participants study two lists of items and, after study of list 1, receive a cue to either forget or continue remembering this list. Following study of list 2, all participants are asked to recall the items of the two lists, irrespective of original cuing. As compared with remember-cued participants, forget-cued participants typically recall more list 2 items and fewer list 1 items, referred to as *list 2 enhancement* and *list 1 forgetting* (for reviews, see Bäuml, Pastötter & Hanslmayr, 2010; MacLeod, 1998). The finding demonstrates that a forget cue can improve recall of subsequently encoded, supposedly relevant material and, simultaneously, can impair recall of previously encoded, supposedly irrelevant information.

B. Pastötter (✉) · O. Kliegl · K.-H. T. Bäuml (✉)
Department of Experimental Psychology, Regensburg University, 93040, Regensburg, Germany
e-mail: bernhard.pastoetter@psychologie.uni-regensburg.de
e-mail: karl-heinz.baeuml@psychologie.uni-regensburg.de

Accounts of list-method directed forgetting

In earlier work, directed forgetting has been attributed to a single mechanism responsible for both list 2 enhancement and list 1 forgetting. The selective rehearsal account, for instance, assumes that during list 2 encoding, participants in the remember condition rehearse both list 2 and list 1 items, whereas in the forget condition, they selectively rehearse the list 2 items, thus improving later recall of list 2 at the expense of list 1 (R. A. Bjork, 1970). The retrieval inhibition account assumes that forget-cued participants engage in active inhibitory processes that reduce access to the list 1 context and, due to the resulting decrease in the list's interference potential, facilitate memory for list 2 items (Geiselman, Bjork & Fishman, 1983). Finally, the context change account claims that the forget cue induces a change in participants' internal context, which then impairs list 1 recall, due to a mismatch between the context at encoding and the context at retrieval, and improves later list 2 recall, due to a reduction in interference (Sahakyan & Kelley, 2002).

According to one-mechanism accounts of directed forgetting, list 2 enhancement and list 1 forgetting are the two sides of the same coin and, thus, should always occur together. Recently, however, a number of dissociations between the two effects have been reported. For instance, whereas list 1 forgetting has been found to be present irrespective of encoding style, list 2 enhancement has arisen for intentionally encoded material but not for incidentally encoded items (e.g., Sahakyan & Delaney, 2003; Sahakyan, Delaney & Waldum, 2008b); whereas list 1 forgetting has been reported to be present in recall but to be absent in recognition, list 2 enhancement has arisen in both recall and recognition (e.g., Benjamin, 2006; Sahakyan & Delaney, 2005); regarding electrophysiological brain activities, list 1 forgetting and list 2 enhancement have been found to be related to separate effects in oscillatory brain function (Bäuml, Hanslmayr, Pastötter & Klimesch, 2008).

On the basis of such dissociations, more recently, two-mechanism accounts of directed forgetting have been suggested, according to which list 1 forgetting and list 2 enhancement arise from different mechanisms. In particular, it has been suggested that the forgetting reflects reduced accessibility of list 1 items at retrieval and the enhancement reflects a change in list 2 encoding. Sahakyan and Delaney (2003), for instance, proposed a two-mechanism account that attributes list 1 forgetting to a change in internal context and list 2 enhancement to a change in encoding strategy, with more elaborate encoding of list 2 items after a forget cue than after a remember cue. Pastötter and Bäuml (2010) proposed a two-mechanism account that attributes list 1 forgetting to retrieval inhibition and list 2 enhancement to a reset of encoding processes. According to the reset-of-encoding hypothesis, the forget cue abolishes memory load and inattentional encoding that would build up when both lists were to be remembered, thus making the encoding of early list 2 items as effective as the encoding of early list 1 items (for related results in other paradigms, see Pastötter, Bäuml & Hanslmayr, 2008; Pastötter, Schicker, Niedernhuber & Bäuml, 2011). While both reset of encoding and selective rehearsal emphasize a role of encoding in list-method directed forgetting, the selective-rehearsal account, but not the reset-of-encoding account, assumes that list 2 enhancement is related to the same mechanism that produces list 1 forgetting.

Serial position curves and the possible role of list output order in directed forgetting

The reset-of-encoding hypothesis arose from analyses of items' serial position curves, showing that the forget cue impairs recall of all list 1 items but improves recall of early list 2 items only (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009). Pastötter and Bäuml (2010) examined directed forgetting of word lists with varying number of list 2 items. On the basis of the data of 280 participants, pooled across three experiments, their analysis of serial position curves indicated that, regarding list 1, forgetting arises for all list items and does not vary in amount with the items' serial list position; regarding list 2, enhancement was not present for all list items but was restricted to the first four items of the list. Moreover, when the number of studied list 2 items was increased, forgetting of list 1 items increased, whereas enhancement of the early list 2 items was unaffected, suggesting that the list 2 reset effect does not depend on list 1 forgetting. Sahakyan and Foster used verbal action phrases as item material to analyze items' serial position curves. Their analysis of serial position curves showed that forgetting is equal for all list 1 items, which is consistent with the Pastötter and Bäuml (2010) finding, and that enhancement is restricted to the first eight list 2 items. Sahakyan and Foster broke the item lists into bins of four serial positions, whereas Pastötter and Bäuml (2010) did not categorize list positions, which may explain the slight variation in results across studies. The results from both studies, however, suggest that, regarding list 2, serial position curves of cuing conditions converge from early to middle serial positions.

The finding that middle and late list 2 items may not be affected by the forget cue is challenging for theoretical accounts of directed forgetting. This holds for all accounts that assume that list 1 forgetting reflects reduced accessibility of the list items—for example, retrieval inhibition (e.g., Geiselman et al., 1983; Pastötter & Bäuml, 2010) and the context change account (Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002). Indeed, if the forget cue reduces accessibility of list 1 items—be it by means of retrieval inhibition or a change in participants' internal context—interference for the list 2 items should be reduced, and thus, accessibility of list 2 items should be enhanced. Both prior behavioral and computational modeling work suggests that a beneficial effect of interference reduction should not be restricted to any subset of list 2 but should arise for all list 2 items about equally (Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann & Usher, 2005; Neath & Brown, 2006). This suggestion contrasts with the previous directed-forgetting findings of enhanced recall of early but not of middle and late list 2 items.

Although the serial position results thus may challenge current accounts of directed forgetting, there is also reason to question the generality of these results. A possible reason for why a general enhancement effect arising from reduced interference for all list 2 items may have been missed in the prior serial position work is that, at test, participants in these studies started their recall with list 1 items and recalled list 2 items last (e.g., Pastötter & Bäuml, 2010; Sahakyan &

Foster, 2009). Indeed, recalling list 1 items first may have reinstated the list's interference potential in the forget condition and, thus, may have reduced subsequent list 2 enhancement. Corresponding evidence arises from work indicating that the successful retrieval of some of the to-be-forgotten list 1 items can eliminate the forgetting of the remaining list items (Bäuml & Samenieh, 2010, 2012b) and from work showing that reexposure of some list 1 items as distractor items in a partial list 2 recognition test can eliminate subsequent list 2 enhancement for the remaining list items (E. L. Bjork & Bjork, 1996; for related results, see Bäuml & Samenieh, 2012a; Goernert & Larson, 1994).

If prior reprocessing of (some of the) list 1 items can reinstate the list's interference potential in the forget condition and, thus, reduce subsequent list 2 enhancement, list 2 enhancement should depend on list output order: If list 2 was recalled first, list 1's interference potential should remain low, and list 2 enhancement should be high; in contrast, if list 1 was recalled first, list 1's interference potential should be reinstated, and list 2 enhancement should be low. The general enhancement effect for list 2 items arising from interference reduction (Davelaar et al., 2005; Neath & Brown, 2006) thus should mainly be present if list 2 was recalled first but be largely absent if list 1 was recalled first. We addressed the issue in the present study by examining whether (and how) list output order affects (serial position curves in) directed forgetting, with regard to both list 2 enhancement and list 1 forgetting.[1]

The present experiments

The goal of the present study was to examine (serial position curves in) directed forgetting (1) with "pure" measures of list 2 enhancement and list 1 forgetting—that is, measures of list 2 enhancement when list 2 is recalled first and measures of list 1 forgetting when list 1 is recalled first—and (2) as a function of list output order. In Experiment 1, each participant took part in a standard directed-forgetting task, either in the forget or the remember condition. In both cuing conditions, participants recalled both item lists at test, either list 1 first or list 2 first. We examined mean recall rates and serial position curves for both item lists, as a function of cue and as a function of the lists' output order. In Experiment 2, each participant took part in a standard directed-forgetting task, in both the forget and the remember conditions. This time, each participant ran three successive blocks of the two directed-forgetting tasks and, in both cuing conditions, recalled to-be-remembered information only—that is, list 2 items in the forget condition and both list 2 items (first) and list 1 items (second) in the remember condition. We examined mean recall rates and serial position curves for list 2 items.

Several predictions arose. First, on the basis of the view that the forget cue reduces list 1 items' interference potential (e.g., Geiselman et al., 1983; Sahakyan & Kelley, 2002) and the finding that successful retrieval of list 1 items at test can reactivate the list's interference potential (e.g., Bäuml & Samenieh, 2010; E. L. Bjork & Bjork, 1996), we expected that mean list 2 enhancement would be larger when list 2 was recalled first than when list 1 was recalled first (Experiment 1). Second, because all list 2 items should benefit from the cue-induced reduction in list 1 interference (Davelaar et al., 2005; Neath & Brown, 2006), we expected list 2 enhancement to be present for all list 2 items when list 2 was recalled first; in particular, if both general interference reduction for all list 2 items and reset of encoding of early list 2 items (e.g., Pastötter & Bäuml, 2010) contributed to the list 2 enhancement effect, the enhancement effect for early list 2 items might even exceed the enhancement effect for the middle and late list 2 items (Experiment 1, Experiment 2). In contrast, if list 1 was recalled first and the list's interference potential was reinstated, no general interference reduction for the list 2 items should arise and only reset of encoding of early list 2 items should contribute to the enhancement effect (Experiment 1; e.g., Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009). Third, regarding list 1, we expected the same amount of forgetting for all list 1 items, thus following both recent serial position work (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009) and the predictions of the retrieval inhibition and the context change accounts (Experiment 1). Such forgetting might be larger if list 2 was recalled first than if list 1 was recalled first, although only if the additional retrieval trials on list 2 items increased the forgetting similarly as additional list 2 study trials do (e.g., Pastötter & Bäuml, 2010).

Experiment 1

Experiment 1 reports a directed-forgetting experiment in which both cuing and list output order were manipulated between participants. Participants studied a first list of items, received a remember or forget cue, and then studied a second list of items. After list 2 study, participants were asked to recall the two item lists, either list 1 first and list 2 second or vice versa. Mean recall rates and serial position

[1] Golding and Gottlob (2005) already examined the effect of list output order in list-method directed forgetting. They employed a within-participants design in which all participants were cued to forget list 1 and to remember list 2. The results showed that participants recalled more (to-be-remembered) list 2 items than (to-be-forgotten) list 1 items when list 2 was recalled first, but not when list 2 was recalled last, suggesting an effect of list output order in directed forgetting. However, because no remember condition was included in this study, the results do not allow separate conclusions on the effect of list output order on list 2 enhancement and list 1 forgetting.

curves were analyzed as a function of list, cuing condition, and list output order. The results of the experiment will shed light on the role of list output order in list-method directed forgetting. In particular, they will show whether, when list 2 is recalled first, list 2 enhancement is present for all list items and whether the enhancement is larger for early than for middle to late list items.

Method

Participants Two hundred seventy-two students (121 males and 151 females) at Regensburg University participated in Experiment 1. They were tested individually, with 68 participants in each of the four experimental conditions.

Materials Twenty-four unrelated German nouns of medium frequency were drawn from the CELEX database using the Wordgen v1.0 software toolbox (Duyck, Desmet, Verbeke & Brysbaert, 2004). Two lists of 12 words each were prepared. Across lists, words were matched on frequency and word length. The assignment of items to lists was constant for all participants. Item order within lists was random for each participant. Each list was equally often used in the remember condition and the forget condition and served equally often as the first and the second presented list.

Design The experiment had a 2 × 2 design with the between-participants factors of cue (remember, forget) and list output order (list 1 recalled first, list 2 recalled first). Conditions differed in which cue was provided after list 1. In the remember condition, list 1 was followed by a cue to remember the items; in the forget condition, list 1 was followed by a cue to forget the items. Conditions also differed in list output order; either list 1 or list 2 was recalled first.

Procedure The multiple-cue version of list-method directed forgetting was used: Participants were told that they would be presented with two lists of words to be learned but that, following each list, they will be given a cue to remember or forget the previous list (e.g., Conway & Fthenaki, 2003; MacLeod, 1999; Pastötter & Bäuml, 2007, 2010; Zellner & Bäuml, 2006). Twelve list 1 items were presented auditorily with a presentation rate of 2 s. In the remember condition, list 1 was followed by the cue to remember the list; in the forget condition, list 1 was followed by the cue to forget the list. Next, 12 list 2 items were presented auditorily with a presentation rate of 2 s; all participants were instructed to remember list 2 items. Participants then counted backward aloud from a three-digit number in steps of threes for 30 s as a recency control. At test, participants were asked to recall the two lists' items regardless of original cuing. Participants in the forget condition were explicitly told that the forget cue had been for pretense. Half of the participants were asked to recall list 1 items first and list 2 items last. For the other half of participants, output order of lists was reversed. Participants wrote down the items of the two lists on separate sheets of paper. Recall time for each list was 1 min.

Recall data were analyzed on both the list level and the item level, separately for the two lists. On the list level, proportion of correct recall was analyzed as a function of cue and list output order. Items were counted as correctly recalled if recalled with the correct list. We also analyzed intrusion errors from the wrong list as a function of cue and list output order. As it turned out, intrusion errors were infrequent and did not differ between remember-cued and forget-cued participants, for either list 1 or list 2. Therefore, we do not report on the detailed results from these analyses. On the item level, proportion of correct recall was analyzed as a function of cue, list output order, and the within-participants factor of serial position. Doing so, each of the two lists was broken into four bins spanning three items each (bin 1, items 1–3; bin 2, items 4–6; bin 3, items 7–9; bin 4, items 10–12). Actually, bin selection did not affect the results, being the same when the data were analyzed with a three-bin selection. In none of the analyses reported in the results section was list 1 or list 2 included as a factor (see Anderson, 2005, for a discussion of confounding variables when comparing list 1 and list 2 recall in a within-participants design of list-method directed forgetting).

Results

List 2 recall On the list level, list 2 recall rates as a function of cue and list output order are shown in Fig. 1a. A 2 × 2 analysis of variance (ANOVA) with the factors of cue (remember vs. forget) and list output order (list 1 recalled first vs. list 2 recalled first) revealed a main effect of cue, $F(1, 268) = 22.23$, $MSE = .03$, $p < .001$, partial $\eta^2 = .08$, and a main effect of list output order, $F(1, 268) = 11.63$, $MSE = .03$, $p < .001$, partial $\eta^2 = .04$; list 2 recall rates were higher when list 2 was recalled first than when it was recalled last (42.3% vs. 35.2%), and forget-cued participants showed higher list 2 recall than did remember-cued participants (43.6% vs. 33.9%). In addition, an interaction between cue and list output order arose, $F(1, 268) = 10.45$, $MSE = .03$, $p < .001$, partial $\eta^2 = .04$; a beneficial effect of the forget cue was present when list 2 was recalled first (50.5% vs. 34.0%), $t(134) = 6.10$, $p < .001$, $d = 1.05$, but not when list 2 was recalled last (36.8% vs. 33.7%), $t(134) < 1$.

On the item level, list 2 recall rates as a function of cue, list output order, and serial position are depicted in Fig. 1b. A 2 × 2 × 4 ANOVA with the factors of cue (remember vs. forget), list output order (list 1 recalled first vs. list 2 recalled first), and serial position (bin 1 vs. bin 2 vs. bin 3 vs. bin 4) was calculated. Consistent with the list-level analysis above,

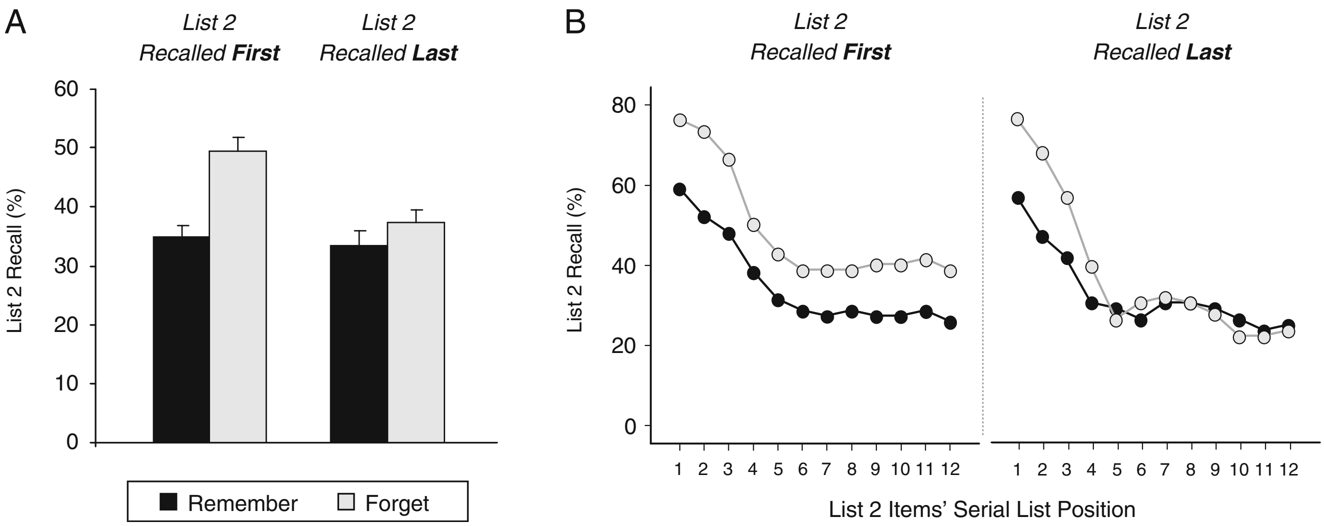

Fig. 1 List 2 recall rates in Experiment 1. **a** On the list level, recall rates are shown as a function of cue and list output order. Error bars: standard errors. **b** On the item level, recall rates are plotted as a function of cue, list output order, and serial position

the ANOVA revealed a main effect of cue, $F(1, 268) = 19.94$, $MSE = .12$, $p < .001$, partial $\eta^2 = .07$, a main effect of list output order, $F(1, 268) = 11.97$, $MSE = .12$, $p < .001$, partial $\eta^2 = .04$, and a cue × list output order interaction, $F(1, 268) = 7.56$, $MSE = .12$, $p < .01$, partial $\eta^2 = .03$. Going beyond the list-level analysis, the ANOVA showed a main effect of serial position, $F(3, 804) = 81.54$, $MSE = .08$, $p < .001$, partial $\eta^2 = .23$, and a cue × serial position interaction, $F(3, 804) = 4.73$, $MSE = .08$, $p < .01$, partial $\eta^2 = .02$; other interactions were nonsignificant, Fs < 1.10, ps > .38.

The main effect of serial position indicates that recall for bin 1 items (61.0%) was higher than recall for bin 2 (35.3%), $t(271) = 10.59$, $p < .001$, $d = .83$, bin 3 (31.0%), $t(271) = 11.76$, $p < .001$, $d = .99$, and bin 4 (27.5%), $t(271) = 13.54$, $p < .001$, $d = 1.10$, items; recall for bin 2 items was higher than recall for bin 4 items, $t(271) = 3.21$, $p < .01$, $d = 0.26$; other differences were nonsignificant, ts(271) < 1.60, ps > .10. More important, due to the reliable cue × serial position interaction, pairwise comparisons of the enhancement effect were calculated. Enhancement was higher for bin 1 items than for bin 2, $F(1, 268) = 7.03$, $MSE = .08$, $p < .01$, partial $\eta^2 = .03$, bin 3, $F(1, 268) = 9.44$, $MSE = .08$, $p < .01$, partial $\eta^2 = .03$, and bin 4, $F(1, 268) = 9.69$, $MSE = .08$, $p < .01$, partial $\eta^2 = .03$, items; all other differences were nonsignificant, Fs < 1. Whereas this differential enhancement effect was not affected by list output order, output order reduced the general enhancement level when list 2 was recalled last. Consistently, when list 2 was recalled last, significant enhancement arose for bin 1 items only (66.1% vs. 48.0%), $t(134) = 3.47$, $p < .01$, $d = 0.59$, but not for bin 2 (31.8% vs. 29.9%), $t(134) < 1$, bin 3 (28.4% vs. 31.4%), $t(134) < 1$, or bin 4 (21.1% vs. 24.0%), $t(134) < 1$, items.

List 1 recall On the list level, list 1 recall rates as a function of cue and list output order are shown in Fig. 2a. A 2 × 2 ANOVA with the factors of cue (remember vs. forget) and list output order (list 1 recalled first vs. list 2 recalled first) revealed a main effect of cue, $F(1, 268) = 18.28$, $MSE = .03$, $p < .001$, partial $\eta^2 = .06$, and a main effect of list output order, $F(1, 268) = 4.03$, $MSE = .03$, $p < .05$, partial $\eta^2 = .02$, but no interaction between the two factors, $F(1, 268) < 1$. Indeed, list 1 recall rates were higher when list 1 was recalled first, as compared with when it was recalled second (32.4% vs. 28.2%), and forget-cued participants showed lower list 1 recall than did remember-cued participants (25.8% vs. 34.8%).

On the item level, list 1 recall rates as a function of cue, list output order, and serial position are depicted in Fig. 2b. A 2 × 2 × 4 ANOVA with the factors of cue (remember vs. forget), list output order (list 1 recalled first vs. list 2 recalled first), and serial position (bin 1 vs. bin 2 vs. bin 3 vs. bin 4) was calculated. Consistent with the list-level analysis above, the ANOVA revealed main effects of cue, $F(1, 268) = 16.69$, $MSE = .12$, $p < .001$, partial $\eta^2 = .06$, and list output order, $F(1, 268) = 4.23$, $MSE = .12$, $p < .05$, partial $\eta^2 = .02$. Going beyond the list-level analysis, the ANOVA showed a main effect of serial position, $F(3, 804) = 128.81$, $MSE = .06$, $p < .001$, partial $\eta^2 = .33$, but no reliable interactions, Fs < 1. Indeed, list 1 recall decreased from the first to the last item bin (55.0% vs. 30.0% vs. 20.1% vs. 16.3%), all ts(271) > 2.00, ps < .05. In fact, forget-cued participants showed lower list 1 recall than did remember-cued participants at all four item bins, all Fs(1, 268) > 4.60, all ps < .05, all partial η^2s > .02, regardless of the lists' output order, all Fs(1, 268) < 1. These results indicate that list 1 forgetting

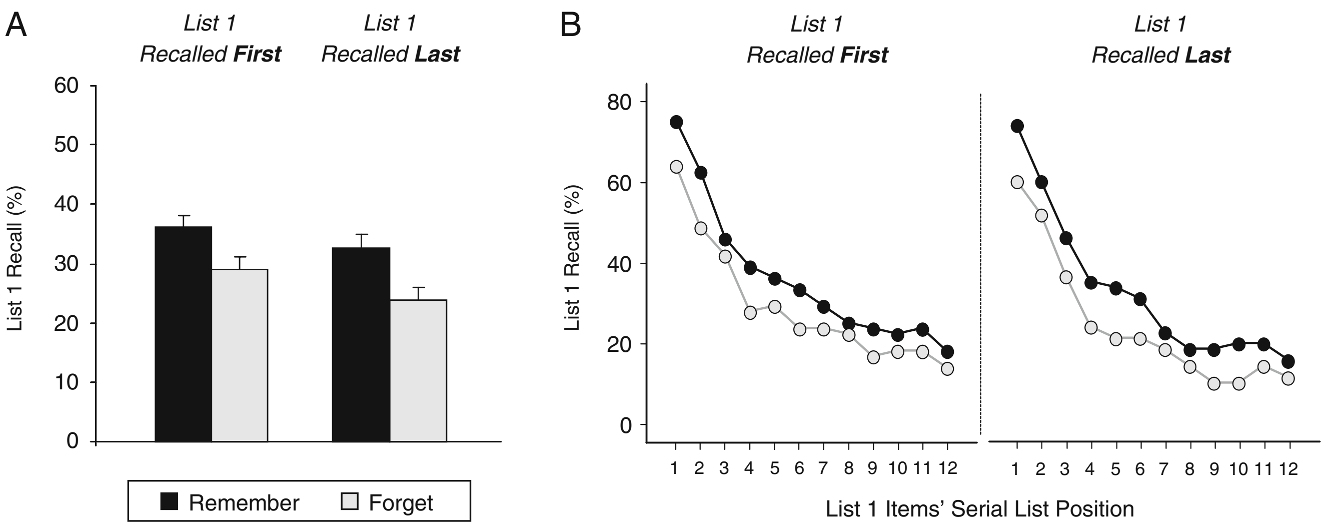

Fig. 2 List 1 recall rates in Experiment 1. **a** On the list level, recall rates are shown as a function of cue and list output order. Error bars: standard errors. **b** On the item level, recall rates are plotted as a function of cue, list output order, and serial position

arises for all items equally and does not depend on the lists' output order.

Discussion

The results of Experiment 1 show the two typical directed-forgetting effects, list 1 forgetting and list 2 enhancement. As was expected, mean list 2 enhancement varied with list output order: Reliable list 2 enhancement arose only when list 2 was recalled first, but it did not arise when list 1 was recalled first, suggesting that recalling list 1 items first reinstated the list's interference potential in the forget condition and, thus, reduced subsequent list 2 enhancement. The finding for list 2 contrasts with the results for list 1. Mean list 1 forgetting was present regardless of list output order. This held although list output order per se affected the results and list 1 recall was generally higher when list 1 was recalled first than when list 1 was recalled last. List output order thus seems to have different influences on the two directed-forgetting effects.

Serial position analysis of the two lists showed higher levels of list 2 enhancement for early list 2 items than for middle and late list 2 items. This differential effect did not depend on list output order, although the items' general amount of enhancement varied with output order. Indeed, enhancement for the middle and late list items was present only when list 2 was recalled first, but it was absent when list 1 was recalled first; the latter finding replicates the results from previous studies in which list 1 was recalled first (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009). Serial position analysis also showed that list 1 forgetting does not vary with the items' serial position. List 1 forgetting arose for all list items, and it arose regardless of whether list 1 was recalled first or last. The finding replicates prior results by Sahakyan and Foster and by Pastötter and Bäuml (2010), who asked participants to recall list 1 first and list 2 second, and generalizes it to the reversed output order.

Experiment 2

An intriguing feature of the results of Experiment 1 is that list 2 enhancement seems to be higher for early than for middle and late list items, regardless of list output order. Because this result may have implications for theoretical accounts of directed forgetting, it was the goal of Experiment 2 to replicate this differential enhancement effect, using different materials and a different experimental setup than was employed in Experiment 1. A directed-forgetting experiment is reported, in which each participant ran three successive experimental blocks, with each block including both the remember and the forget conditions. In both cuing conditions, participants recalled to-be-remembered information only—that is, list 2 items in the forget condition and both list 2 items (first) and list 1 items (second) in the remember condition. Doing so, we created "pure" measures of list 2 recall and, thus, "pure" measures of list 2 enhancement. List 2 mean recall rates and list 2 serial position curves were analyzed as a function of cuing condition. On the basis of the results of Experiment 1, we expected that list 2 enhancement would be present for all list 2 items, with higher list 2 enhancement for early than for middle and late list items.

Method

Participants Eighty-two students (25 males and 57 females) at Regensburg University participated in Experiment 2.

They were tested individually. None of the participants had taken part in Experiment 1.

Materials One hundred forty-four unrelated German nouns of medium frequency were drawn from the CELEX database (Duyck et al., 2004). They were assigned to 12 item lists, each consisting of 12 items. The assignment of items to lists was random for all participants.

Design The experiment had a 2 × 3 design with the within-participants factors of cue (remember, forget) and block (blocks 1–3). Each of three blocks consisted of the two directed-forgetting tasks, differing in which cue was provided after list 1. In the remember task, list 1 was followed by a cue to remember the items; in the forget task, list 1 was followed by a cue to forget the items.

Procedure The multiple-cue version of list-method directed forgetting was used. The experiment consisted of three blocks, each containing a remember and a forget task that differed in which cue was provided after list 1. Order of the remember and the forget tasks within each block was randomized. Each participant ran six study–test cycles, each containing two lists. In one half of the cycles, list 1 was cued to be forgotten; in the other half, list 1 was cued to be remembered. List 2 was always cued to be remembered. By using three blocks rather than a single block, we increased the signal-to-noise ratio for serial-position data analysis. In each task, participants studied two lists of 12 items each, counted backward, and were tested. All items were presented visually in the center of a computer screen, with a presentation rate of 4 s (3.5-s item presentation, 0.5-s blank screen). After study of list 1, participants received a cue to either forget or continue remembering this list. Next, 12 list 2 items were presented visually, with a presentation rate of 4 s; all participants were instructed to remember list 2 items. Participants then counted backward aloud from a three-digit number in steps of threes for 30 s as a recency control. At test, focus was on list 2 recall. In the forget condition, participants were asked to remember list 2 items only. In the remember condition, participants were asked to remember list 2 items first and list 1 items second. Participants wrote down the items of each list on separate sheets of paper. Recall time for each list was 1 min.

List 2 recall data were analyzed on both the list level and the item level. On the list level, proportion of correct recall was analyzed as a function of cue and block. Items were counted as correctly recalled if recalled with the correct list. On the item level, proportion of correct recall was analyzed as a function of cue, block, and the within-participants factor of serial position (bin 1, items 1–3; bin 2, items 4–6; bin 3, items 7–9; bin 4, items 10–12). The results were the same for a three-bin selection. We also analyzed intrusion errors from the wrong list or wrong block as a function of cue and block. As it turned out, both extra-block and intra-block intrusion errors were very infrequent and did not differ between remember-cued and forget-cued participants. Therefore, we do not report on the detailed results from these analyses. List 1 recall data are also not reported, because we did not ask participants to recall list 1 items in the forget condition.

Results

On the list level, list 2 recall rates as a function of cue and block are shown in Fig. 3a. A 2 × 3 ANOVA with the factors of cue (remember vs. forget) and block (block 1 vs. block 2 vs. block 3) revealed a main effect of cue, $F(1, 81) = 54.16$, $MSE = .02$, $p < .001$, partial $\eta^2 = .40$, and a main effect of block, $F(2, 162) = 7.49$, $MSE = .02$, $p < .001$, partial $\eta^2 = .09$, but no interaction between the two factors, $F(2, 162) < 1$. Indeed, recall increased across blocks (50.9% vs. 54.7% vs. 57.5%), and forget-cued participants showed higher list 2 recall than did remember-cued participants (59.6% vs. 49.2%).

On the item level, list 2 recall rates as a function of cue and serial position are depicted in Fig. 3b. A 2 × 3 × 4 ANOVA with the factors of cue (remember vs. forget), block (block 1 vs. block 2 vs. block 3), and serial position (bin 1 vs. bin 2 vs. bin 3 vs. bin 4) was calculated. Consistent with the list-level analysis above, the ANOVA revealed main effects of cue, $F(1, 81) = 60.19$, $MSE = .08$, $p < .001$, partial $\eta^2 = .43$, and block, $F(2, 162) = 6.20$, $MSE = .08$, $p < .01$, partial $\eta^2 = .07$. Going beyond the list-level analysis, the ANOVA revealed a main effect of serial position, $F(3, 243) = 14.03$, $MSE = .08$, $p < .001$, partial $\eta^2 = .15$, and a cue × serial position interaction, $F(3, 243) = 3.06$, $MSE = .08$, $p < .05$, partial $\eta^2 = .04$; other interactions were nonsignificant, *F*s < 1.70, *p*s > .12. The main effect of serial position indicates that recall for bin 1 items (66.5%) was higher than recall for bin 2 (52.1%), $t(81) = 8.29$, $p < .001$, $d = 0.66$, bin 3 (49.0%), $t(81) = 8.27$, $p < .001$, $d = 0.77$, and bin 4 (50.0%), $t(81) = 7.32$, $p < .001$, $d = 0.76$, items; all other differences were nonsignificant, $ts(81) < 1.70$, *p*s > .10.

Due to the reliable cue × serial position interaction, post hoc analyses were calculated, indicating a beneficial effect of the forget cue for bin 1 (77.0% vs. 55.8%), $t(81) = 7.86$, $p < .001$, $d = 0.87$, bin 2 (56.1% vs. 48.1%), $t(81) = 2.74$, $p < .01$, $d = 0.31$, bin 3 (52.4% vs. 45.7%), $t(81) = 2.68$, $p < .01$, $d = 0.26$, and bin 4 (52.9% vs. 47.1%), $t(81) = 2.11$, $p < .05$, $d = 0.23$, items. Crucially, pairwise comparisons showed that enhancement for bin 1 items was larger than enhancement for bin 2, $F(1, 81) = 13.31$, $MSE = .03$, $p < .001$, partial $\eta^2 = .14$, bin 3, $F(1, 81) = 15.74$, $MSE = .03$, $p < .001$, partial $\eta^2 = .16$, and bin 4, $F(1, 81) = 15.70$, $MSE = .03$, $p < .001$, partial $\eta^2 = .16$, items; all other

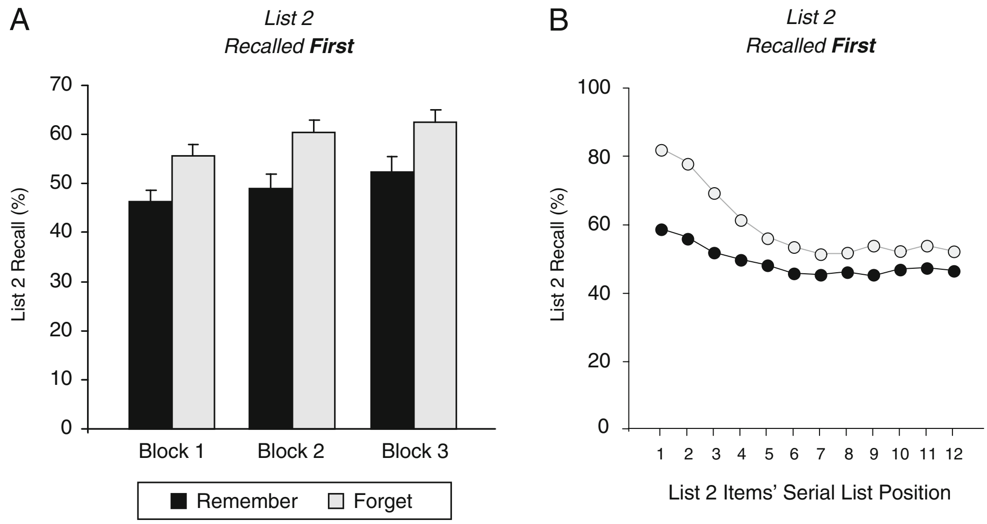

Fig. 3 List 2 recall rates in Experiment 2. **a** On the list level, recall rates are shown as a function of cue and block. Error bars: standard errors. **b** On the item level, recall rates are plotted as a function of cue and serial position, collapsed across block conditions

differences between middle and late bins were nonsignificant, $F\text{s} < 1$. Thus, cuing affected all list 2 items, with a larger effect for early list 2 items than for middle and late list 2 items.

Discussion

Consistent with the results of Experiment 1, Experiment 2 showed that when list 2 items are recalled first, list 2 enhancement arises. Also consistent with the results of Experiment 1, serial position analysis showed that the enhancement is present for all list items but is larger for early than for middle and late list 2 items. Additionally, the results of Experiment 2 show that list 2 recall can increase across successive runs of the two cuing conditions, presumably arising from more effective learning across study–test cycles (e.g., Postman, 1971). Such increases in recall level did not affect list 2 enhancement.

General discussion

Directed forgetting and the role of list output order

The present results show that, in list-method directed forgetting, list 2 enhancement depends on list output order. While both Experiment 1 and Experiment 2 demonstrate that the forget cue enhances memory for list 2 items if, at test, list 2 is recalled first, the results of Experiment 1 show that list 2 enhancement is reduced if list 1 is recalled first. A different picture arises for the detrimental effect of the forget cue on recall of list 1 items. In contrast to list 2 enhancement, list 1 forgetting is present both when list 1 is recalled first and when list 2 is recalled first, and the size of the forgetting does not vary with list output order.

The present finding that list output order can affect list 2 enhancement is consistent with the hypothesis that, at test, initial list 1 recall can reinstate the list's interference potential and, thus, reduce or even eliminate subsequent list 2 enhancement. The finding thus confirms prior work showing that guided cued recall of some to-be-forgotten list 1 items can eliminate forgetting of the remaining list items (Bäuml & Samenieh, 2010, 2012b) and showing that reexposure of some to-be-forgotten list 1 items can eliminate subsequent list 2 enhancement (Bjork & Bjork, 1996). The present finding that list output order does not influence list 1 forgetting suggests that, although list 1 forgetting increases with number of list 2 study trials (Pastötter & Bäuml, 2010), additional retrieval trials on list 2 items do not further increase the forgetting.

While, in the present study, single experimental conditions differed in whether list 1 or list 2 was recalled first at test, in the literature, single studies differ in which of the two lists was recalled first. Indeed, while, in some studies, participants were asked to recall list 1 first (e.g., Delaney & Sahakyan, 2007; Pastötter & Bäuml, 2010), in other studies, participants were asked to recall list 2 first (e.g., E. L. Bjork & Bjork, 1996; Kimball & Bjork, 2002) or to recall the two lists' items in any order they wished, thus inducing a tendency to recall the more recent list 2 items first (e.g., Geiselman et al., 1983; Golding & Gottlob, 2005). Interestingly, when list 1 was recalled first, quite often list 1 forgetting was present, whereas list 2 enhancement was absent (e.g., Delaney & Sahakyan, 2007; Pastötter & Bäuml, 2010); in contrast, when list 2 was recalled first or the two lists' items were recalled simultaneously, quite often robust list 2 enhancement arose (e.g., E. L. Bjork & Bjork, 1996; Geiselman et al., 1983). While this difference in results across studies may be due to a number of uncontrolled factors, such as differences in materials, procedure, or even participants, and there are exceptions to this "rule" as well (e.g., Bäuml et al., 2008; Sahakyan & Kelley, 2002), the difference in results may well be related to the difference in the lists' output order.

We addressed the issue in a meta-analysis that we conducted on list-method directed-forgetting studies of the past 10 years. The main result of the meta-analysis can be seen in Fig. 4 (for detailed methods and results, see the Appendix; note that directed-forgetting studies before the year 2000 typically used a within-participants directed-forgetting design in which no remember condition was included). It shows mean weighted effect sizes of list 2 enhancement and list 1 forgetting as a function of list output order. Categorical model fitting suggests that whereas list 1 forgetting did not depend on the lists' output order in the prior work, list 2 enhancement was much larger when list 2 was recalled first, as compared with when it was recalled last. The results of this meta-analysis are consistent with the present finding that list 2 enhancement, but not list 1 forgetting, depends on list output order. In particular, the results support the view that list 2 enhancement is present mainly if, at test, list 2 is recalled first.

Serial position curves in directed forgetting

Regarding serial position curves of list 1, the results of Experiment 1 show that the forgetting does not vary with items' serial list position. List 1 forgetting arose for all list items, and it arose regardless of whether list 1 was recalled first or last. The finding that the forgetting is equal for all list 1 items replicates the results from prior work on items' serial position curves, in which participants were asked to recall list 1 items first and list 2 items second (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009). The finding is also in line with the results of two further studies, which showed largely parallel list 1 serial position curves in the two cuing conditions, both when list 1 was recalled first (Lehman & Malmberg, 2009) and when participants were asked to recall the two lists' items in any order they wished (Geiselman et al., 1983), although no detailed test statistics were reported in these studies. Together, the results from the present and previous studies suggest that the forget cue reduces accessibility of the whole list, affecting all list 1 items about equally.[2]

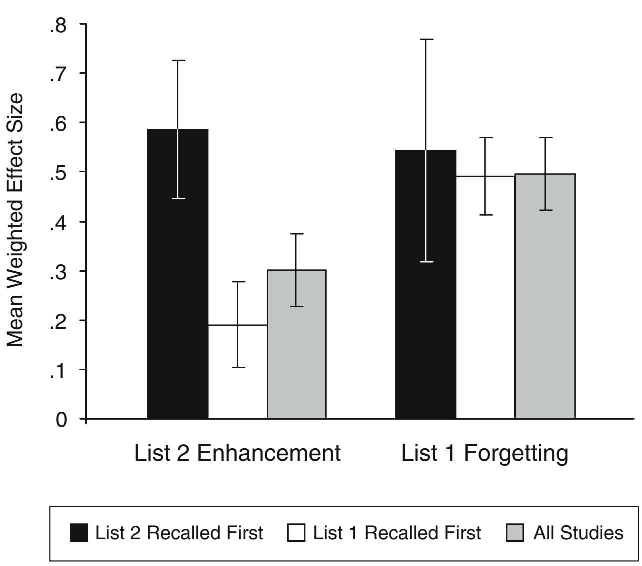

Fig. 4 Meta-analysis on 20 list-method directed-forgetting studies of the past 10 years: Mean weighted effect sizes of list 2 enhancement (list 2 recall in the forget condition minus list 2 recall in the remember condition) and list 1 forgetting (list 1 recall in the remember condition minus list 1 recall in the forget condition), with confidence intervals (95% CIs), calculated for all studies and separately for studies in which list 2 was recalled first and list 1 was recalled last (including those in which participants recalled the two lists in any order they wished) and studies in which list 1 was recalled first and list 2 was recalled last. For detailed method and results of the meta-analysis, see the Appendix

Regarding serial position curves of list 2, the results of Experiment 1 and Experiment 2 demonstrate that early list 2 items differ in the size of the enhancement effect from the middle and late list items. Indeed, when list 2 is recalled first, all list 2 items show recall enhancement, but the early list items show a larger enhancement effect than do the middle and late items; when list 1 is recalled first, only the early list 2 items show recall enhancement, while the enhancement is absent for middle and late list items. These results are in agreement with prior work showing enhancement of early list 2 items when participants recalled list 1 items first (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009). They are also in line with the results of two other studies, which showed whole-list enhancement with a tendency of increased enhancement for early list items, both when list 2 was recalled first (Lehman & Malmberg, 2009) and when participants recalled the two lists in any order they wished (Geiselman et al., 1983), although again no detailed test statistics were reported in these studies. As a whole, the findings indicate that list 2 enhancement depends on list output order and that two different factors can contribute to the enhancement effect: one factor that is restricted to early list 2 items and is present regardless of list output order, and another factor that pertains to all list 2 items and is present only if list 2 is recalled first.

A new two-mechanism account of directed forgetting

According to the two-mechanism accounts of directed forgetting suggested by Sahakyan and Delaney (2003) and

[2] Employing a within-participants design in which all participants were cued to forget list 1 and to remember list 2, MacLeod, Dodd, Sheard, Wilson and Bibi (2003, Experiment 1) compared serial position curves for the two item lists. The results showed a primacy recall advantage for the first two list 2 items when compared with recall of list 1 items. However, because no remember condition was included in this experiment, the results do not allow separate conclusions on list 2 enhancement and list 1 forgetting. In a second experiment, MacLeod and colleagues employed a standard between-participants design to examine serial position curves in list-method directed forgetting. However, the results did not show any reliable list 1 forgetting.

Pastötter and Bäuml (2010), list 2 enhancement arises from a change in list 2 encoding processes, either via a change in encoding strategy or via a reset of the encoding process, whereas list 1 forgetting reflects reduced accessibility of list 1 items, either via inhibition of the list 1 context or via a change in participants' internal context. Regarding list 1 forgetting, the present results are consistent with the view that the forget cue impairs access to the list 1 context and, thus, affects the single list items about equally. Regarding list 2 enhancement, however, the present results are in disagreement with the prior two-mechanism accounts, both the strategy-change view (Sahakyan & Delaney, 2003) and the reset-of-encoding view (Pastötter & Bäuml, 2010).

Indeed, the strategy-change hypothesis claims that the enhancement effect is caused by a change in people's encoding strategy, with more elaborate encoding of list 2 items in the forget condition than in the remember condition. Thus, list 2 enhancement should be present for all list 2 items, regardless of the lists' output order (Glanzer & Koppenaal, 1977). Finding the enhancement to be restricted to early list 2 items when list 1 is recalled first, is in disagreement with the hypothesis. The reset-of-encoding hypothesis claims that cuing participants to forget list 1 selectively boosts encoding of early list 2 items, with stronger primacy effects in the forget condition than in the remember condition. Accordingly, list 2 enhancement should be present for early list items, but not for middle and late list items (Pastötter & Bäuml, 2010). Finding list 2 enhancement for all list items when list 2 is recalled first is in disagreement with this proposal.

While the present results thus challenge these previous two-mechanism accounts, they are consistent with a modified version of Pastötter and Bäuml's (2010) two-mechanism account. This new account still assumes that the forget cue induces a reset of encoding for early list 2 items, selectively boosting encoding of these items. Additionally, however, it assumes that, by inhibiting the list 1 context, the forget cue causes interference reduction for all list 2 items and, thus, can improve retrieval of these items at test (see Davelaar et al., 2005; Neath & Brown, 2006). Crucially, whereas the reset is supposed to reflect an encoding effect and to be effective regardless of list output order, the beneficial effect of interference reduction is supposed to reflect a retrieval effect that is present only if list 2 is recalled first and list 1's interference potential is not reactivated by prior recall of the list. Thus, both reset of encoding and interference reduction are assumed to contribute to list 2 enhancement when list 2 is recalled first, whereas mainly reset of encoding but less interference reduction are assumed to contribute when list 1 is recalled first.

The present view that two different factors may contribute to list 2 enhancement is consistent with Lehman and Malmberg's (2009) recently proposed computational model of remembering and forgetting in multiple lists, which assumes that both interference reduction and differential encoding of early list 2 items contribute to the enhancement effect in list-method directed forgetting. Following Sahakyan and Kelley (2002), the model assumes that the forget cue causes a change in mental context between lists, which creates less overlap in contextual features between the two lists and, thus, reduces list 1 interference when list 2 items are recalled at test. In addition, the model assumes that the forget cue improves encoding of the context that is associated with the first item of list 2. Such improved encoding is proposed to contribute to the enhancement effect, because participants may initiate list 2 recall with the first list item and subsequently recall items from nearby positions through interitem associations.

Importantly, the Lehman and Malmberg (2009) model not only predicts differential list 2 enhancement, but also predicts differential list 1 forgetting. Indeed, the model assumes that, at encoding, context information is most strongly associated to the first item of list 1 and that, at retrieval, the initial list 1 retrieval cue is a pure context cue. The model then predicts that the forget cue makes initial recall of the first list 1 item less effective, because of a less effective context cue, and thus produces larger forgetting for early than for middle and late list items. The model's predictions are in line with Lehman and Malmberg's (2009) observation that the forget cue reduces chances that participants start list 1 recall with the list's first item. However, the predictions are in conflict with all the prior work reporting comparable forgetting for all list 1 items (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009; see also Geiselman et al., 1983; Lehman & Malmberg, 2009; present Experiment 1). Possibly, Lehman and Malmberg's (2009) finding of reduced initial recall of the list's first item points to a change in retrieval strategy, rather than to differential list 1 forgetting when a forget cue is provided.

A practical recommendation

To date, only few list-method directed-forgetting studies have reported "pure" measures of both list 1 forgetting and list 2 enhancement—that is, measures of list 2 enhancement when list 2 was recalled first and measures of list 1 forgetting when list 1 was recalled first (e.g., Aslan, Zellner & Bäuml, 2010; Kimball & Bjork, 2002; Lehman & Malmberg, 2009). Rather, most studies have measured the two directed-forgetting effects by using a fixed recall order—that is, by asking participants to recall list 1 first and list 2 second, or vice versa, or by asking participants to recall the two lists' items in any order they wish. While gaining "pure" measures of list 1 forgetting and list 2 enhancement appears to be the best choice to measure the two effects, the present results show that asking participants to recall list 2 first and list 1 second leads to measures of similar quality—that is, perfect measures of list 2 enhancement and hardly affected measures of list 1 forgetting. In contrast, when participants are asked to recall list 1 first and list 2 second, perfect measures of list 1 forgetting will arise, but list 2 enhancement may be largely underestimated.

Future work on list-method directed forgetting may find these findings useful. In clinical, neuroscientific, or developmental studies, sometimes only limited numbers of participants are available for an experiment, so that the experimenter may prefer a fixed output order at test, rather than varying the lists' output order across participants. If so, the present results indicate that experimenters should ask participants to recall the second list first and the first list last. Such list output order should guarantee perfect (list 2) or at least reasonable (list 1) measures of people's directed forgetting.

Conclusions

The present study demonstrates that list output order affects list 2 enhancement, but not list 1 forgetting, in list-method directed forgetting. List 2 enhancement is present mainly when list 2 is recalled first but is reduced, or even absent, when list 1 is recalled first. Recalling list 1 items first seems to reinstate the list's interference potential in the forget condition and, thus, to reduce subsequent list 2 enhancement. This influence of list output order is confirmed by a meta-analysis conducted on prior directed-forgetting studies. In addition, the present results indicate that two separate factors can contribute to list 2 enhancement: one (encoding) factor that is restricted to early list 2 items and does not depend on the lists' output order, and another (retrieval) factor that pertains to all list 2 items and varies with the lists' output order. The results are consistent with a new two-mechanism account, according to which list 1 forgetting is caused by inhibition of the list 1 context, whereas both reset of encoding of early list 2 items and inhibition-induced interference reduction for all list 2 items contribute to the enhancement effect.

Authors Note Correspondence concerning this article should be addressed to Bernhard Pastötter or Karl-Heinz T. Bäuml, Department of Experimental Psychology, Regensburg University, 93040 Regensburg, Germany. E-mail: bernhard.pastoetter@psychologie.uni-regensburg.de or karl-heinz.baeuml@psychologie.uni-regensburg.de.

Appendix

Method and results of the meta-analysis

Method

The meta-analysis was conducted on list-method directed-forgetting studies of the past 10 years (starting from 2002). Articles were collected via PubMed Internet search (www.pubmed.gov) with the keywords *directed forgetting* and *intentional forgetting*, and by checking the references in each of the collected articles. The four main criteria for inclusion of a study in the analysis were as follows: (1) Cuing was manipulated *between* healthy adult participants; (2) *word lists* were used as item material; (3) lists' *output order* was reported and related unambiguously to the presented data; (4) items' *encoding style* was not manipulated, but all items were encoded intentionally. On the basis of these criteria, 20 studies in 15 articles were included in the meta-analysis (Table 1).

In all calculations and procedures for categorical model fitting, we followed the approach by Hedges and Olkin (1985). For each study, weighted effect sizes of list 2 enhancement (d_E) and list 1 forgetting (d_F) were calculated by subtracting mean recall rates between cuing conditions (list 2 recall in the forget condition minus list 2 recall in the remember condition; list 1 recall in the remember condition minus list 1 recall in the forget condition) and dividing by the unbiased standard deviations. When means or standard deviations were not reported, inferential statistics were used to determine effect sizes. Across studies, mean weighted effect sizes of list 2 enhancement (D_E) and list 1 forgetting (D_F) and confidence intervals (95% CIs) were calculated, both across all studies and separately for list-output-order groups (group 1, studies in which list 2 was recalled first and list 1 was recalled last and studies in which participants recalled the two lists in any order they wished; group 2, studies in which list 1 was recalled first and list 2 was recalled last).

In categorical model fitting, our first step was to determine whether the studies' effect sizes of list 2 enhancement (d_Es) were homogeneous (Q_T, total variance). The same was done regarding the single effect sizes of list 1 forgetting (d_Fs). In the next step, we broke down the studies into the two list-output-order groups (group 1 vs. group 2). To test for between-group and within-group homogeneity, we computed Q_B (between-group variance) and Q_W (within-group variance), separately for list 2 enhancement and list 1 forgetting. Both statistics have an approximate chi-square distribution with $p - 1$ (Q_B: where p is the number of between-groups) and $k - p$ (Q_W: where k is the total number of effect sizes within groups) degrees of freedom. A significant between variance (Q_B) indicates that the mean weighted effect size, D_E or D_F, differs between list-output-order groups. A significant within variance (Q_W) indicates that substantial heterogeneity is in the model that is not accounted for by the lists' output order.

Results

Across all studies, the average weighted effect sizes of list 2 enhancement, D_E = 301, 95% CI = [.227, .374], and list 1 forgetting, D_F = 496, 95% CI = [.422, .570],

Table 1 Studies along with sample size, output order, list length, and effect size of list 1 forgetting and list 2 enhancement

Studies included in the Meta-Analysis	N	Output Order	List Length	d_F	$S(d_F)$	d_E	$S(d_E)$
Delaney & Sahakyan (2007, Experiment 1)	88	List 1 first	15	0,708	0,155	0,142	0,151
Foster & Sahakyan (2011, overt conditions)	80	List 1 first	16	0,334	0,159	0,334	0,159
Kimball & Bjork (2002, Experiment 1)	90	List 1 only	15	0,630	0,153		
	90	List 2 only	15			0,525	0,152
Lehman & Malmberg (2009, Experiment 1)	90	List 1 only	16	0,315	0,150		
	90	List 2 only	16			0,787	0,155
Lehman & Malmberg (2011, unrelated items)	80	List 1 only	16	0,297	0,159		
	80	List 2 only	16			0,816	0,165
Mulji & Bodner (2010, unrelated items)	52	List 1 first	12	0,206	0,197	0,229	0,197
Pastötter & Bäuml (2007)	108	List 1 first	15	0,352	0,137	0,224	0,136
Pastötter & Bäuml (2010, Experiment 1, 15 item conditions)	64	List 1 first	15	0,663	0,182	0,021	0,177
Pastötter & Bäuml (2010, Experiment 2, 15 item conditions)	144	List 1 first	15	0,499	0,120	0,145	0,118
Pastötter & Bäuml (2010, Experiment 3, 15 item conditions)	72	List 1 first	15	0,703	0,172	0,039	0,167
Sahakyan, Delaney, & Goodmon (2008, Experiment 1)	64	List 1 first	12	0,663	0,182	0,041	0,177
Sahakyan, Delaney, & Goodmon (2008, Experiment 2)	64	List 1 first	12	0,497	0,180	0,000	0,177
Sahakyan & Goodmon (2007, Experiment 1, unrelated conditions)	48	List 1 first	16	0,674	0,210	0,393	0,206
Sahakyan & Goodmon (2007, Experiment 2, unrelated conditions)	48	List 1 first	16	0,477	0,207	0,430	0,206
Sahakyan & Kelley (2002, Experiment 1, standard conditions)	88	List 1 first	15	0,292	0,152	0,332	0,152
Sahakyan & Kelley (2002, Experiment 2, not reinstated conditions)	64	List 1 first	15	0,652	0,181	0,466	0,179
Spillers & Unsworth (2011)	50	List 1 first	15	0,608	0,205	-0,070	0,200
Wessel & Merckelbach (2006, combined for item conditions)	108	List 2 first	15	0,495	0,138	0,265	0,137
Zellner & Bäuml (2006, Experiment 1)	18	List 2 first	12	0,856	0,348	0,465	0,338
Zou, Zhang, Huang, & Weng (2011, Experiment 2, healthy controls)	30	List 2 first	10	0,541	0,263	0,892	0,271

N = sample size; d_F = weighted effect size of list 1 forgetting; $S(d_F)$ = estimated standard deviation of d_F; d_E = weighted effect size of list 2 enhancement; $S(d_E)$ = estimated standard deviation of d_E

were significant, indicating reliable directed-forgetting effects (Fig. 4). Model fitting showed that the distribution of effect sizes of the single studies was homogeneous for list 1 forgetting, $Q_T \sim \chi^2(19) = 17.79$, $p = .537$, but not for list 2 enhancement, $Q_T \sim \chi^2(19) = 45.21$, $p < .001$. Therefore, we broke down studies into list-output-order groups and tested for between-group and within-group homogeneity. Regarding list 2 enhancement, list-output-order groups reliably differed, $Q_B \sim \chi^2(1) = 22.45$, $p < .001$, and showed within-group homogeneity, $Q_W \sim \chi^2(18) = 22.75$, $p = .20$, both in group 1, $Q_W \sim \chi^2(5) = 10.74$, $p = .06$, and in group 2, $Q_W \sim \chi^2(13) = 12.01$, $p = .53$. Although different in effect size, list 2 enhancement was reliable in both groups (group 1, $D_E = .587$, 95% CI = [.447, .726]; group 2, $D_E = .190$, 95% CI = [.104, .277; see Fig. 4). Regarding list 1 forgetting, list-output-order groups did not differ, $Q_B \sim \chi^2(1) = 0.18$, $p = .67$, and showed within-group homogeneity, $Q_W \sim \chi^2(18) = 17.62$, $p = .48$. List 1 forgetting was reliable in both groups (group 1, $D_F = .544$, 95% CI = [.317, .770]; group 2, $D_F = .492$, 95% CI = [.413, .570]; see Fig. 4). Together, the results of the meta-analysis suggest that, in prior work, list 2 enhancement was reliably larger when list 2 was recalled first, as compared with when list 2 was recalled last, whereas list 1 forgetting was unaffected by list output order.

References

Studies included in the meta-analysis are marked with an asterisk (*)

Anderson, M. C. (2005). The role of inhibitory control in forgetting unwanted memories: A consideration of three methods. In C. M. MacLeod & B. Uttl (Eds.), *Dynamic cognitive processes* (pp. 159–190). Tokyo: Springer.

Aslan, A., Zellner, M., & Bäuml, K.-H. T. (2010). Working memory capacity predicts listwise directed forgetting in adults and children. *Memory, 18,* 442–450.

Bäuml, K.-H. [T.], Hanslmayr, S., Pastötter, B., & Klimesch, W. (2008). Oscillatory correlates of intentional updating in episodic memory. *NeuroImage, 41,* 596–604.

Bäuml, K.-H. [T.], Pastötter, B., & Hanslmayr, S. (2010). Binding and inhibition in episodic memory: Cognitive, emotional, and neural

processes. *Neuroscience & Biobehavioral Reviews, 34,* 1047–1054.
Bäuml, K.-H. T., & Samenieh, A. (2010). The two faces of memory retrieval. *Psychological Science, 21,* 793–795.
Bäuml, K.-H. T., & Samenieh, A. (2012a). Influences of part-list cuing on different forms of episodic forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 366–375.
Bäuml, K.-H. T., & Samenieh, A. (2012b). Selective memory retrieval can impair and improve retrieval of other memories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 488–494.
Benjamin, A. S. (2006). The effects of list-method directed forgetting on recognition memory. *Psychonomic Bulletin & Review, 13,* 831–836.
Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. *Consciousness and Cognition, 5,* 176–196.
Bjork, R. A. (1970). Positive forgetting: The noninterference of items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior, 9,* 255–268.
Conway, M. A., & Fthenaki, A. (2003). Disruption of inhibitory control of memory following lesions to the frontal and temporal lobes. *Cortex, 39,* 667–686.
Davelaar, E. J., Goshen-Gottstein, Y., Ashkenazi, A., Haarmann, H. J., & Usher, M. (2005). The demise of short-term memory revisited: Empirical and computational investigations of recency effects. *Psychological Review, 112,* 3–42.
(*) Delaney, P. F., & Sahakyan, L. (2007). Unexpected costs of high working memory capacity following directed forgetting and contextual change manipulations. *Memory & Cognition*, *35*, 1074–1082.
Duyck, W., Desmet, T., Verbeke, L., & Brysbaert, M. (2004). Wordgen: A tool for word selection and non-word generation in Dutch, German, English, and French. *Behavior Research Methods, Instruments, & Computers, 36,* 488–499.
(*) Foster, N. L., & Sahakyan, L. (2011). The role of forget-cue salience in list-method directed forgetting. *Memory*, *19*, 110–117.
Geiselman, R. E., Bjork, R. A., & Fishman, D. (1983). Disrupted retrieval in directed forgetting: A link with posthypnotic amnesia. *Journal of Experimental Psychology: General, 112,* 58–72.
Glanzer, M., & Koppenaal, L. (1977). The effect of encoding tasks on free recall: Stages and levels. *Journal of Verbal Learning and Verbal Behavior, 16,* 21–28.
Goernert, P. N., & Larson, M. E. (1994). The initiation and release of retrieval inhibition. *Journal of General Psychology, 121,* 61–66.
Golding, J. M., & Gottlob, L. R. (2005). Recall order determines the magnitude of directed forgetting in the within-participants list method. *Memory & Cognition, 33,* 588–594.
Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. New York: Academic Press.
(*) Kimball, D. R., & Bjork, R. A. (2002). Influences of intentional and unintentional forgetting on false memories. *Journal of Experimental Psychology: General*, *131*, 116–130.
(*) Lehman, M., & Malmberg, K. J. (2009). A global theory of remembering and forgetting from multiple lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 970–988.
(*) Lehman, M., & Malmberg, K. J. (2011). Overcoming the effects of intentional forgetting. *Memory & Cognition*, *39*, 335–347.
MacLeod, C. M. (1998). Directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 1–57). Mahwah, NJ: Erlbaum.
MacLeod, C. M. (1999). The item and list methods of directed forgetting: Test differences and the role of demand characteristics. *Psychonomic Bulletin & Review, 6,* 123–129.
MacLeod, C. M., Dodd, M. D., Sheard, E. D., Wilson, D. E., & Bibi, U. (2003). In opposition to inhibition. In B. H. Ross (Ed.), *The psychology of learning and motivation* (pp. 163–214). New York: Elsevier Science.
(*) Mulji, R., & Bodner, G. E. (2010). Wiping out memories: New support for a mental context change account of directed forgetting. *Memory*, *18*, 763–773.
Neath, I., & Brown, G. D. A. (2006). SIMPLE: Further applications of a local distinctiveness model of memory. *Psychology of Learning and Motivation, 46,* 201–243.
(*) Pastötter, B., & Bäuml, K.-H. (2007). The crucial role of postcue encoding in directed forgetting and context-dependent forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 977–982.
(*) Pastötter, B., & Bäuml, K.-H. (2010). Amount of postcue encoding predicts amount of directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 54–65.
Pastötter, B., Bäuml, K.-H., & Hanslmayr, S. (2008). Oscillatory brain activity before and after an internal context change: Evidence for a reset of encoding processes. *NeuroImage, 43,* 173–181.
Pastötter, B., Schicker, S., Niedernhuber, J., & Bäuml, K.-H. T. (2011). Retrieval during learning facilitates subsequent memory encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 287–297.
Postman, L. (1971). Transfer, interference and forgetting. In J. W. Kling & L. A. Riggs (Eds.), *Experimental psychology* (pp. 1019–1132). New York: Holt, Rinehart, & Winston.
Sahakyan, L., & Delaney, P. F. (2003). Can encoding differences explain the benefits of directed forgetting in the list method paradigm? *Journal of Memory and Language, 48,* 195–206.
Sahakyan, L., & Delaney, P. F. (2005). Directed forgetting in incidental learning and recognition testing: support for a two-factor account. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 789–801.
(*) Sahakyan, L., Delaney, P. F., & Goodmon, L. B. (2008a). Oh, honey, I already forgot that: Strategic control of directed forgetting in older and younger adults. *Psychology and Aging*, *23*, 621–633.
Sahakyan, L., Delaney, P. F., & Waldum, E. R. (2008b). Intentional forgetting is easier after two "shots" than one. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 408–414.
Sahakyan, L., & Foster, N. L. (2009). Intentional forgetting of actions: Comparison of list-method and item-method directed forgetting. *Journal of Memory and Language, 61,* 134–152.
(*) Sahakyan, L., & Goodmon, L. B. (2007). The influence of directional associations on directed forgetting and interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 1035–1049.
(*) Sahakyan, L., & Kelley, C. M. (2002). A contextual change account of the directed forgetting effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 1064–1072.
(*) Spillers, G. J., & Unsworth, N. (2011). Are the costs of directed forgetting due to failures of sampling or recovery? Exploring the dynamics of recall in list-method directed forgetting. *Memory & Cognition*, *39*, 403–411.
(*) Wessel, I., & Merckelbach, H. (2006). Forgetting "murder" is not harder than forgetting "circle": Listwise-directed forgetting of emotional words. *Cognition & Emotion*, *20*, 129–137.
(*) Zellner, M., & Bäuml, K.-H. (2006). Inhibitory deficits in older adults: list-method directed forgetting revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 290–300.
(*) Zou, Z., Zhang, J. X., Huang, X., & Weng, X. (2011). Impaired directed forgetting in abstinent heroin addicts. *Memory*, *19*, 36–44.