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List-method directed forgetting: Evidence for the reset-of-encoding hypothesis employing item-recognition testing

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In list-method directed forgetting (LMDF), people are cued to forget a previously studied item list (List 1) and to learn a new list of items (List 2) instead. Such cuing typically enhances memory for the List 2 items, in both recall and (sometimes) item-recognition testing. It has recently been hypothesized that the enhancement effect for List 2 items (partly) reflects the result of a reset-of-encoding process. The proposal is that encoding efficacy decreases with an increase in study material, but the forget cue can reset the encoding process to make the encoding of early List 2 items as effective as the encoding of early List 1 items. An experiment is reported that examined the reset-of-encoding hypothesis with item-recognition testing, examining influences of items' serial learning position on the effects of the forget cue. Item-recognition tests were conducted separately for the two lists. Consistent with the reset-of-encoding hypothesis, the results showed strong enhancement effects for early List 2 items, but hardly any enhancement effects for middle and late List 2 items. Like in previous item-recognition studies, no cuing effects were found for List 1 items. The results support two-mechanism accounts of LMDF, which assume a critical role for a reset-of-encoding process for List 2 enhancement.

Keywords: List-method directed forgetting; Item recognition; Reset of encoding.

Research on list-method directed forgetting (LMDF) has shown that people's memory for new information can be enhanced by cuing them to forget older information (Bjork, 1972, 1989). In the LMDF paradigm, participants study two lists of items. Study of List 1 is followed either by a cue to forget the list or by a cue to remember the list; study of List 2 is always followed by a cue to remember the list. At test, when participants' memory for the two lists' items is tested irrespective of original cuing, the typical finding in recall tests is that forget-cued participants recall more List 2 items and fewer List 1 items than remember-cued participants; the two effects of the forget cue are referred to as List 2 enhancement and List 1 forgetting in the following (for reviews on LMDF, see Bäuml, Pastötter, & Hanslmayr, 2010; MacLeod, 1998; Sahakyan, Delaney, Foster, & Abushanab, 2013).

To account for the two effects of the forget cue, one-mechanism accounts of LMDF have been suggested, attributing List 2 enhancement and List 1 forgetting to a single underlying mechanism. The retrieval–inhibition account, for instance, assumes that, during study of List 2, forget-cued participants engage in active inhibitory processes

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which, at test, impair access to the List 1 context and, because of the resulting decrease in the list's interference potential, improve recall of List 2 items (Geiselman, Bjork, & Fishman, 1983). Alternatively, the context-change account assumes that, when cued to forget, participants deliberately change mental context which, at test, impairs access to the List 1 context and, because of the resulting decrease in proactive interference, improves recall of List 2 items (Sahakyan & Kelley, 2002; for further one-mechanism accounts, see MacLeod, 1998).

Challenging one-mechanism views on LMDF, a number of dissociations between the two effects of the forget cue have recently been reported, indicating that, in recall tests, List 2 enhancement can be present without List 1 forgetting (e.g., Aslan & Bäuml, 2013; Pastötter & Bäuml, 2010), and List 1 forgetting can be present without List 2 enhancement (e.g., Pastötter & Bäuml, 2010; Sahakyan & Delaney, 2003). Moreover, when comparing LMDF effects between recall and item-recognition testing, List 1 forgetting seems to be the more robust of the two effects in recall (see recent meta-analysis by Pastötter, Kliegl, & Bäuml, 2012), but List 2 enhancement to be the more robust of the two effects in item recognition. Consistently, in previous item-recognition studies, either List 2 enhancement was found to be present without List 1 forgetting (Benjamin, 2006; Sahakyan & Delaney, 2005), or both effects were absent (Geiselman et al., 1983; Schmitter-Edgecombe, Marks, Wright, & Ventura, 2004; Whetstone, Cross, & Whetstone, 1996).

On the basis of such dissociations, two-mechanism accounts of LMDF have been suggested, attributing the two effects of the forget cue to different underlying mechanisms. Sahakyan and Delaney (2003), for instance, proposed that List 1 forgetting arises from impaired access to the List 1 context due to a mental context change between the study of lists, and List 2 enhancement from improved encoding of List 2 items due to a change in forget-cued participants' encoding strategy, leading to more elaborate encoding of List 2 items in the forget than in the remember condition. Alternatively, Pastötter and Bäuml (2010) suggested that List 1 forgetting is due to inhibition-induced impaired access to the List 1 context and List 2 enhancement arises from improved encoding of List 2 primacy items, as is reflected in the reset-of-encoding hypothesis. This hypothesis claims that encoding efficacy decreases with an increase of study material, i.e., decreases from List 1 encoding to List 2 encoding, due to inattentional encoding and increasing memory load. Such increase in memory load for List 2 items, for instance, may arise from memory reactivation and competition of previously encoded List 1 items (Bäuml, Hanslmayr, Pastötter, & Klimesch, 2008; Conway, Harries, Noyes, Racsma'ny, & Frankish, 2000). In particular, the hypothesis assumes that the forget cue can abolish memory load and inattentional encoding, and thus make the encoding of (early) List 2 items as effective as the encoding of (early) List 1 items.

Results from both neurocognitive and behavioural work are consistent with the reset-of-encoding hypothesis. In the neurocognitive studies, encoding efficacy and reset of encoding were related to oscillatory alpha power (8–14 Hz), showing that stimulus-induced alpha power during item encoding increases with an increase in study material, both within and across item lists, but that a forget cue can disrupt such increase in alpha power. Single-list studies showed that alpha power during the encoding of single items is negatively related to items' recall probability and, specifically, increases from the encoding of early list items to the encoding of middle and late list items (Sederberg et al., 2006; Serruya, Sederberg, & Kahana, 2014). Similarly, multiple-list studies showed that alpha power during encoding increases from the encoding of earlier lists to the encoding of later lists and such increase is negatively related to recall success (Pastötter, Bäuml, & Hanslmayr, 2008; Pastötter, Schicker, Niedernhuber, & Bäuml, 2011). In both the single-list and the multiple-list studies, the increase in alpha power with amount of study material was attributed to impoverished item encoding (Pastötter et al., 2008, 2011; Sederberg et al., 2006). Crucially, a recent LMDF study showed that the forget cue can disrupt such increase in alpha power (Hanslmayr et al., 2012). In this study, alpha power during item encoding increased from List 1 to List 2 encoding in the remember condition, but did no longer increase in the forget condition. Consistent with the reset-of-encoding hypothesis, the forget cue reset neural activities for List 2 items back to List 1 level, thus making the encoding of (early) List 2 items as effective as the encoding of (early) List 1 items (for related results in other experimental paradigms, see Pastötter et al., 2008, 2011).

The behavioural evidence for the reset-of-encoding hypothesis arises from recall studies that examined the influence of List 2 items' serial learning position on LMDF on an item-level basis. This work showed that either List 2 enhancement is present for early List 2 items but is absent for middle and late List 2 items (Pastötter & Bäuml, 2010; Sahakyan & Foster, 2009), or List 2 enhancement is present for all List 2 items but is larger for early than for middle- and late-list items (Geiselman et al., 1983; Pastötter et al., 2012). In addition, this work demonstrated that the recall enhancement for early List 2 items is present regardless of which list is recalled first at test, whereas the recall enhancement for middle- and late-List-2 items is present only when List 2 is tested first (Pastötter et al., 2012). The behavioural results thus reveal dissociations between the enhancement effect for early list items and the enhancement effects for middle- and late-list items. These dissociations are consistent with the reset-of-encoding hypothesis, which suggests that the forget cue may reduce memory load and inattentional encoding for List 2, improving encoding efficacy mainly for early List 2 items and less, if at all, for middle- and late-List 2 items.[1]

Whereas prior recall studies examined List 2 enhancement effects on both a list-level and an item-level basis, prior recognition work examined List 2 enhancement effects exclusively on a list-level basis, with partly inconsistent results. Indeed, the forget cue reliably affected List 2 item recognition in some studies (Benjamin, 2006; Sahakyan & Delaney, 2005), but did not so in other studies (Geiselman et al., 1983; Schmitter-Edgecombe et al., 2004; Whetstone et al., 1996). Importantly, no item-recognition study has yet examined List 2 enhancement as a function of the items' serial learning position. Items' serial learning position, however, may affect List 2 enhancement, as is suggested by the reset-of-encoding hypothesis, and mainly early List 2 items, and less middle and late List 2 items, may show enhancement effects in item recognition. Such a finding would be important for our theoretical understanding of List 2 enhancement effects in LMDF because it may help distinguishing between different views on List 2 enhancement (see Discussion). In addition, it might provide a post-hoc explanation of the inconsistency in results in the prior item-recognition work that was done on the list-level basis. In fact, if mainly early List 2 items showed an enhancement effect in item recognition, and the circumstances that surround the experimental settings influenced the amount of enhancement and/or number of early List 2 items that show an enhancement effect, then the likelihood of finding reliable enhancement on the list level may vary across studies and the effect may be observable in some studies, but not in others.

[1] In contrast to the behavioural studies, the neurocognitive studies examined the reset-of-encoding hypothesis on a list-level basis. Examining the hypothesis on an item level would have required much larger data-sets than were employed in this previous work. Future work is required to fill this empirical gap.

An experiment is reported in which LMDF was examined employing item-recognition testing. Participants studied two lists of items. List 1 was followed either by a cue to forget or a cue to remember the list. After study of List 2 and a short distractor task, separate List 2 and List 1 item-recognition tests were conducted. Either List 2 or List 1 was tested first. Item recognition was tested by asking participants to rate their confidence of each item being old or new. Confidence ratings were used to construct item-recognition receiver-operating characteristics (ROCs) that allow to examine LMDF effects on items' memory strength independent of participants' response criteria (e.g., Macmillan & Creelman, 2004; Parks & Yonelinas, 2008). Going beyond prior LMDF work employing item-recognition testing, List 1 and List 2 item recognition data were analyzed on both the list level and the item level. Recognition data were analysed as a function of cuing, items' serial learning position within a list and the two lists' testing order. On the basis of the reset-of-encoding hypothesis (Pastötter & Bäuml, 2010), we expected List 2 enhancement effects mainly for early List 2 items and less for middle- and late List 2 items, regardless of which list was tested first. Cuing was expected to have no effect on recognition of List 1 items (e.g., Benjamin, 2006; Sahakyan & Delaney, 2005).

METHOD

Participants

One hundred students at Regensburg University (71 females; mean age = 22.6 years; SD = 2.2), participated in the study. They were paid 5 Euros for participation.

Material

Two hundred forty unrelated German nouns of medium frequency were drawn from the CELEX database (Duyck, Desmet, Verbeke, & Brysbaert, 2004). For each participant, items were assigned randomly to four 30-item target lists and four 30-item lure lists.

Design

The experiment had a 2 × 2 mixed design with the within-participants factor of CUE (remember and forget) and the between-participants factor of TESTING ORDER (List 2 tested first and List 1 tested 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 list; in the forget condition, List 1 was followed by a cue to forget the list. Conditions also differed according to which list was tested first, List 2 or List 1.

Procedure

Prior to the experiment, participants were told that they would be presented with lists of words to be studied for recognition tests and that, following each list, they would be given a cue to remember or a cue to forget the previously studied list. They were told that to-be-forgotten items would not be tested (Pastötter & Bäuml, 2007, 2010). Each participant then participated in both the remember and the forget condition. Both cuing conditions consisted of an encoding phase, an intermediate phase and a test phase. In the encoding phase, List 1 items were presented in the middle of the screen with a presentation rate of 2 s per item (1.5 s item presentation and 0.5 s blank screen). In the remember condition, List 1 was followed by a cue to remember the list; in the forget condition, it was followed by a cue to forget the list. Next, List 2 target items were presented with the same presentation rate as List 1 items. In both cuing conditions, List 2 was followed by a cue to remember the list. The study phase was followed by an intermediate phase in which participants added pairs of three-digit numbers as fast and accurately as possible for 5 min.

In the test phase, for each of the two cuing conditions, two old–new item-recognition tests were applied, one for List 2 and one for List 1. In each of the two recognition tests, the list's 30 target items and the list's 30 lure items were presented in randomized order. Participants were asked to rate their confidence of each single item being old or new by using a six-point rating scale ranging from *1: Definitely old* to *6: Definitely new*. They were told that they should rate the items regardless of original cuing; in the forget condition, they were explicitly told that the forget cue was only for pretense. Participants were encouraged to use the whole range of the six-point rating scale to specify their degree of confidence. Items were presented in the middle of the screen, together with a rating scale schematically depicted in the lower part of the screen. Participants were asked to enter their responses on a PC keyboard. As soon as a response was entered, the next item was presented. Half of the participants did the List 2 recognition test first and the List 1 recognition test last; for the other half the order was reversed.

Order of cuing conditions was counterbalanced across participants. Participants who completed the remember condition first and the forget condition second experienced no unexpected events until the test phase of the forget condition when they were surprisingly asked to judge List 1 items as old or new. Participants who completed the forget condition first and the remember condition second were confronted with the surprise List 1 recognition test after the first half of the experiment. In this case, the experimenter firmly assured that the participant would not be deceived again (e.g., Bäuml et al., 2008; Bäuml & Samenieh, 2012; Zellner & Bäuml, 2006).

Data analysis

Using signal-detection analysis, List 2 and List 1 item-recognition data were examined both on the basis of single-subject data in an overall analysis and on the basis of group data in ROC analysis. First, on the basis of single-subject data and for comparison with the LMDF literature, an overall analysis was conducted in which overall hit rates (HRs), i.e., number of *old* responses collapsed across confidence ratings *1–3* for targets, and overall false alarm rates (FARs), i.e., number of *old* responses collapsed across confidence ratings *1–3* for lures, were analysed as a function of CUE (remember and forget) and TESTING ORDER (List 2 tested first and List 1 tested first), separately for the two lists.

Next, on the basis of group data, List 2 and List 1 item-recognition ROCs were analysed. ROC curves were created by plotting accumulated

HRs against accumulated FARs across response-criterion points associated with the different levels of the confidence-rating scale, starting with the most confident criterion point to the left (*1: Definitely old*). The unequal-variance signal-detection (UVSD) model was applied to describe the data (Wixted, 2007). The UVSD model assumes that item recognition is based on a single source of memorial information, i.e., general memory strength, and the variance of the memory-strength distribution for old items exceeds that for new items. Note that general memory strength does not imply a single memory process but may reflect the additive combination of various processes, including familiarity and recollection (Wixted & Mickes, 2010).

The UVSD model assumes that participants respond with a given level of confidence whenever their assessment of the memory strength of a presented item exceeds a response criterion, c_i, associated with a given confidence level. Studied items' general memory strength (d') is given by the distance between the means of the underlying strength distributions for the studied items and the lures. The lure distribution is scaled to have a mean of 0 and a standard deviation of 1. All parameters of the UVSD model then are estimated relative to the lure distribution, including the mean (general memory strength, d') and the standard deviation of the target distribution (σ). With five response criteria, the UVSD model has seven free parameters and thus three degrees of freedom for testing the model's goodness of fit to the data (see also Spitzer & Bäuml, 2007).

Parameter estimation and statistical testing were done using maximum likelihood techniques and the Solver(TM) tool in Microsoft Excel (Dunn, 2010). Goodness-of-fit statistics were calculated to test whether the UVSD model was able to describe List 2 and List 1 item-recognition data separately for the single cuing and testing-order conditions. First, we analysed whether d' varied as a function of cuing and testing order separately for the two lists. Second, we analysed whether d' varied as a function of cuing and items' serial learning position separately for the two lists. In this second analysis, both List 2 and List 1 were broken into three item bins spanning 10 items each (Bin 1, Items 1–10; Bin 2, Items 11–20; Bin 3, Items 21–30), and accumulated List 2 and List 1 HRs were calculated for each of the three bins.

TABLE 1
Mean overall hit rates (HRs) and false alarm rates (FARs) as a function of CUE and TESTING ORDER

	List 2			
	List 2 tested first		*List 2 tested last*	
CUE	*HR*	*FAR*	*HR*	*FAR*
Remember	.75	.25	.75	.27
Forget	.80	.24	.78	.22
	List 1			
	List 1 tested first		*List 1 tested last*	
CUE	*HR*	*FAR*	*HR*	*FAR*
Remember	.80	.19	.79	.24
Forget	.81	.19	.77	.25

RESULTS

Overall analysis of individual data

Table 1 shows HRs and FARs as a function of CUE (remember and forget) and TESTING ORDER (List 2 tested first and List 1 tested first), separately for List 2 and List 1.

List 2 HRs and FARs were analysed in two separate 2 × 2 analyses of variance (ANOVAs) with the factors of CUE (remember vs. forget) and TESTING ORDER (List 2 tested first vs. List 2 tested second). Both analyses revealed a main effect of CUE, due to higher List 2 HRs (.79 vs. .75), $F(1,98) = 6.50$, MSE = .011, $p = .012$, partial $\eta^2 = .062$, and lower list-2 FARs (.23 vs. .26), $F(1,98) = 4.43$, MSE = .010, $p = .038$, partial $\eta^2 = .043$, in the forget condition than in the remember condition. Neither a main effect of TESTING ORDER, Fs(1,98) < 1, nor an interaction between the two factors, Fs(1,98) < 2.04, ps >.150, were found.

List 1 HRs and FARs were analysed by analogous ANOVAs. The analyses revealed a marginal significant main effect of TESTING ORDER in List 1 FARs (.19 vs. .25), $F(1,98) = 3.37$, MSE = .043, p =.069, partial η^2 =.033, but no main effect of CUE, for both List 1 HRs (.79 vs. .79) and List 1 FARs (.22 vs. .22), both Fs(1,98) < 1, and no other main effect or interaction, Fs(1,98) < 1.5.[2]

[2]Consistent with prior recall work (Bäuml et al., 2008; Bäuml & Samenieh, 2012; Zellner & Bäuml, 2006), order of cuing conditions did not affect results. For both List 2 and List 1, no main effect or interaction with order of cuing conditions arose, for both HRs and FARs, all ps > .120.

ROC analysis of group data

Figure 1 shows the ROCs obtained by plotting the cumulative HRs against the cumulative FARs, separately for List 2 and List 1 and separately for cuing and testing-order conditions. The figure also depicts the fit of the UVSD model to each single data set. Table 2 shows goodness-of-fit statistics and maximum-likelihood estimates of parameters d' and σ for each single data-set. The statistics indicate that the UVSD fit all data-sets well, *all* χ^2s(3) < 6.03, *all* ps > .120.

In the first step, we examined whether parameter d' varied as a function of cuing (remember and forget) and testing order (List 2 tested first and List 1 tested first), separately for List 2 and List 1. Regarding List 2, the analysis showed that d' was significantly higher in the forget than in the remember condition (1.98 vs. 1.54), $\chi^2(1) = 38.16$, $p < .001$, independent of testing order, $\chi^2(1) < 1$. Testing order did not affect List 2 items' memory strength, $\chi^2(1) = 2.33$, $p = .127$. Regarding List 1, d' did not differ between remember and forget conditions (1.99 vs. 2.01), $\chi^2(1) = 0.06$, $p = .806$, but List 1 items' memory strength was higher when List 1 was tested first than when it was tested second (2.30 vs. 1.74), $\chi^2(1) = 48.72$, $p < .001$.

In the second step, we examined whether cuing effects on parameter d', collapsed across testing-order conditions, depended on items' serial learning position in a list (early, middle, late). Figure 2 shows List 2 and List 1 ROCs together with the best fitting curves of the UVSD model, separately

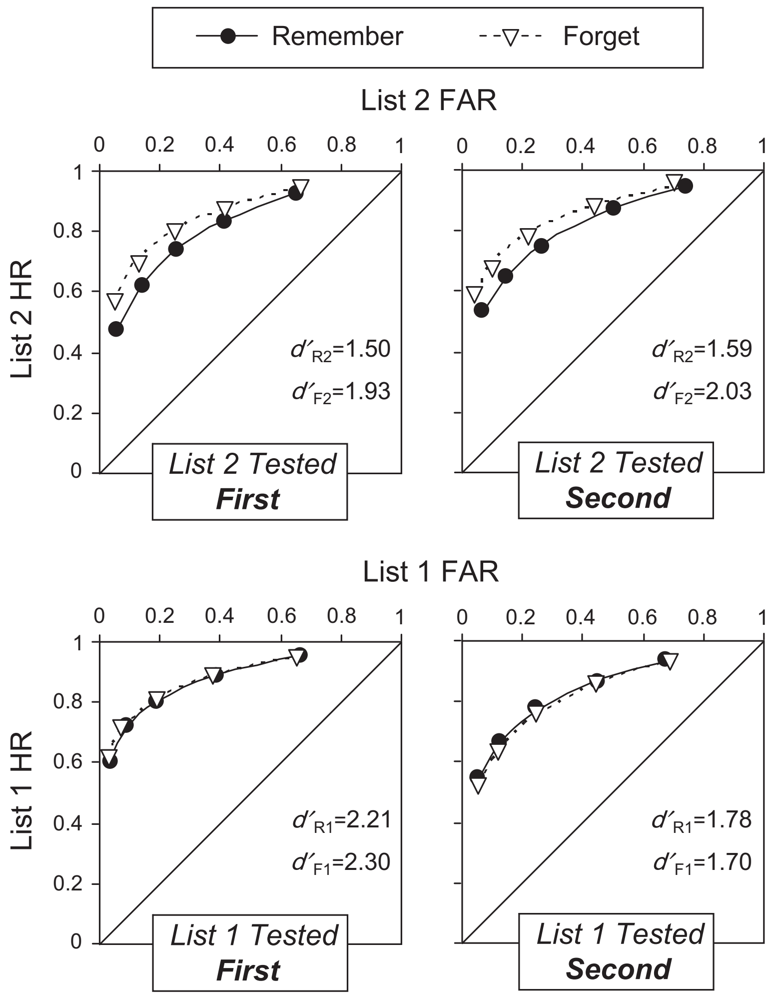

Figure 1. Item-recognition ROCs depicting cumulative hit rates (HRs) and false alarm rates (FARs) in the remember condition (R) and the forget condition (F) as a function of list testing order, separately for the two lists. Lines indicate theoretical item-recognition ROCs derived from the unequal-variance signal detection model.

TABLE 2
Fit of the unequal-variance signal-detection model to the recognition data

	List 2									
	List 2 tested first					*List 2 tested last*				
	Parameter estimates		*Goodness of fit*			*Parameter estimates*		*Goodness of fit*		
CUE	*d′*	σ	χ^2	*df*	*p*	*d′*	σ	χ^2	*df*	*p*
Remember	1.50	1.30	2.10	3	.552	1.59	1.40	1.28	3	.734
Forget	1.93	1.46	2.75	3	.432	2.03	1.53	6.02	3	.111
	List 1									
	List 1 tested first					*List 1 tested last*				
	Parameter estimates		*Goodness of fit*			*Parameter estimates*		*Goodness of fit*		
CUE	*d′*	σ	χ^2	*df*	*p*	*d′*	σ	χ^2	*df*	*p*
Remember	2.21	1.58	2.01	3	.571	1.78	1.47	5.08	3	.166
Forget	2.30	1.75	1.44	3	.696	1.70	1.44	1.68	3	.640

d′ = general memory strength; σ = standard deviation of the target distribution; *df* = degrees of freedom.

for cuing conditions and items' serial learning position. Regarding List 2, the analysis showed that the effect of cuing on *d′* varied with items' serial learning position, $\chi^2(1) = 25.90$, $p < .001$. Consistently, a reliable effect of cuing on List 2 items' memory strength was present for early items (2.56 vs. 1.50), $\chi^2(1) = 55.07$, $p < .001$, but was absent for middle (1.78 vs. 1.58), $\chi^2(1) = 2.90$, $p = .089$, and late List 2 items (1.69 vs. 1.46), $\chi^2(1) = 2.68$, $p = .102$.[3] Regarding List 1, cuing effects were absent at all serial learning positions, $\chi^2(1) = 0.08$, $p = .961$, regardless of which list was tested first, $\chi^2(1) < 1$.[4]

[3] Post-hoc analysis showed that the beneficial effect of cuing on early List 2 items' *d′* was equally present for Items 1–5 (2.61 vs. 1.55) and Items 6–10 (2.09 vs. 1.37), $\chi^2(1) = 1.45$, $p = .229$.

[4] In both steps of the ROC analysis, we also examined whether parameter σ varied as a function of cuing, testing order and item's serial learning position. Regarding List 2, the analyses showed that σ was significantly higher in the forget than in the remember condition (1.50 vs. 1.35), $\chi^2(1) = 5.43$, $p = .020$, independent of both testing order and items' serial position, both $\chi^2(1)$s < 1. Regarding List 1, σ did not differ between the forget and the remember condition (1.57 vs. 1.52), $\chi^2(1) = 0.68$, $p = .410$, but was higher when List 1 was tested first than when it was tested second (1.66 vs. 1.46), $\chi^2(1) = 7.75$, $p = .005$. Other effects were non-significant. Also, note that, in all analyses, σ was significantly larger than 1, all *p*s < .001. This finding is consistent with the UVSD model, which assumes that the standard deviation of the target distribution is larger than the standard deviation of the lure distribution.

DISCUSSION

The results show that cuing in LMDF has a very limited effect on item-recognition memory, with only a subset of List 2 items being affected by the forget instruction. Overall, the List 2 results are in line with prior work showing that List 2 enhancement can be present in item recognition (Benjamin, 2006; Sahakyan & Delaney, 2005). Going beyond this prior work, they show that the enhancement effect in item recognition is present mainly for early List 2 items but is largely absent for middle and late List 2 items, independent of list testing order. List 1 results also fit with previous studies indicating that List 1 forgetting is typically absent in item recognition (Benjamin, 2006; Geiselman et al., 1983; Sahakyan & Delaney, 2005; Schmitter-Edgecombe et al., 2004; Whetstone et al., 1996). In addition, they show that the forgetting is absent for all List 1 items, again independent of list testing order. All of these results arose under conditions in which the two lists were tested separately, thus allowing for separate estimates of FARs for the two lists. Doing so, results revealed generally higher FARs for List 2 than List 1, and a cuing effect on FARs for List 2—with lower FARs in the forget than in the remember condition—but not list 1. These differences between lists were overlooked in the prior work because the two lists were tested simultaneously within a single experimental block.

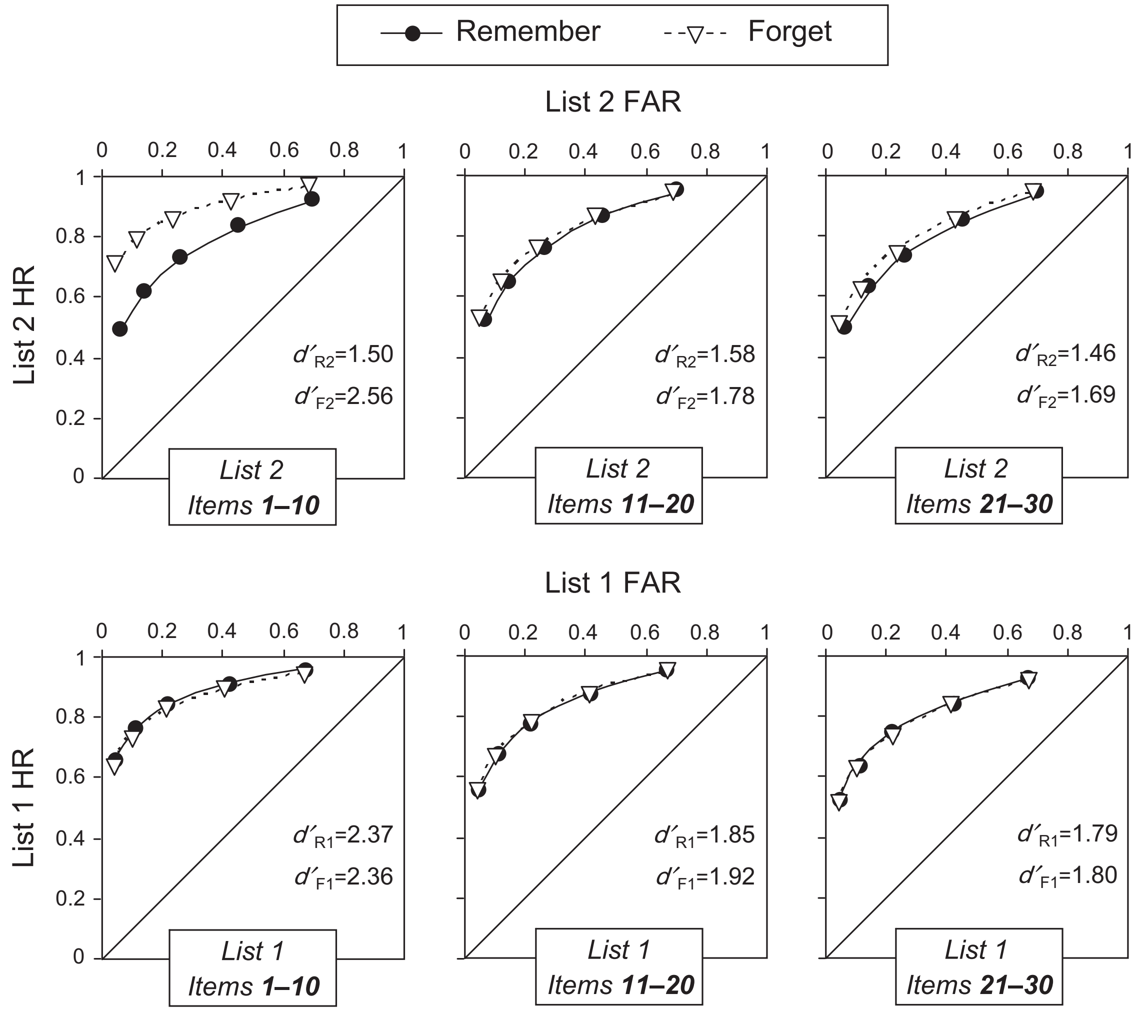

Figure 2. Item-recognition ROCs depicting cumulative hit rates (HRs) and false alarm rates (FARs) in the remember condition (R) and the forget condition (F) as a function of the items' serial learning positions, separately for the two lists. Lines indicate theoretical item-recognition ROCs derived from the unequal-variance signal detection model.

The present results regarding List 2 enhancement are consistent with the reset-of-encoding hypothesis of LMDF (Pastötter & Bäuml, 2010). This hypothesis assumes that encoding efficacy decreases with increasing amount of study material, and thus, in the LMDF task, decreases from List 1 to List 2 in the remember condition. The reduced encoding efficacy is supposed to arise from memory reactivation and competition of the previously encoded List 1 items, leading to inattention and increased memory load for List 2 item encoding. In particular, the hypothesis assumes that the forget cue can abolish memory load and inattentional encoding, which can boost encoding efficacy for early List 2 items in the forget condition, and make the encoding of early List 2 items comparable to the encoding of early List 1 items. The reset-of-encoding hypothesis predicts enhanced encoding and thus improved item recognition for early List 2 items, but not for middle and late List 2 items. The present results show exactly this pattern and therefore are consistent with the hypothesis.

Prior LMDF work already provided support for the reset-of-encoding hypothesis, both neurocognitively and behaviourally. Examining LMDF on a list-level basis, prior neurocognitive work showed that stimulus-induced alpha power increases from List 1 to List 2 encoding in the remember condition but not in the forget condition (Hanslmayr et al., 2012), with increases of alpha power being related to encoding inefficacy (Pastötter et al., 2008, 2011; Sederberg et al., 2006). Examining LMDF on an item-level basis, prior behavioural work employing recall testing showed that the forget cue has a larger effect on recall of early List 2 items than on recall of middle and late List 2 items, indicating a separable enhancement effect for early List 2 items (Geiselman et al., 1983; Pastötter & Bäuml, 2010; Pastötter et al., 2012; Sahakyan & Foster, 2009). The present results complement this prior work by showing for the first time that early List 2 items, but not middle and late List 2 items, show an enhancement effect in item recognition, which supports the idea that the forget cue improves mainly the encoding of early List 2 items.

The reset-of-encoding hypothesis leaves open exactly how many early List 2 items show enhancement effects and how large the enhancement effect is for each single item. Whereas in the present item-recognition study, reliable enhancement effects arose for the first 10 List 2 items, in the prior recall studies, reliable enhancement effects arose for the first four (Pastötter & Bäuml, 2010), the first six (Lehman & Malmberg, 2009) or the first eight (Sahakyan & Foster, 2009) list items. These differences in results suggest that the enhancement effect for the single items may vary with the circumstances that surround an experiment, and enhancement effects on the list level may thus be more easily observable in some studies than in other studies, which is what the prior research showed (Benjamin, 2006; Geiselman et al., 1983; Sahakyan & Delaney, 2005; Schmitter-Edgecombe et al., 2004; Whetstone et al., 1996).

The present results on List 2 enhancement are not easily explained by the strategy-change hypothesis of LMDF (Sahakyan & Delaney, 2003). According to this hypothesis, the forget cue induces a change in participants' encoding strategy, leading to more elaborate encoding of List 2 items in the forget condition than in the remember condition. Because different encoding strategies should affect the encoding for all the items of a list (Glanzer & Koppenaal, 1977), the strategy-change hypothesis predicts that all List 2 items should benefit from a forget cue in item recognition, which is not what the present results show. To reconcile the hypothesis with the present results, the restriction thus would have to be imposed that forget-cued participants change encoding strategy for early List 2 items only and then switch back to less effective encoding for middle and late List 2 items. Such restriction, however, would be in contrast to Glanzer and Koppenaal's (1977) result.

Although the present results thus favour the reset-of-encoding hypothesis over the strategy-change hypothesis of LMDF, they do not rule out that, under certain conditions, there may be an additional role for strategy change in List 2 enhancement. For instance, it could be argued that strategy-change effects may have been missed in the present experiment due to the fast item presentation rate of 2 s per item. Such fast presentation rate may have restricted the range of potential encoding strategies and thus may have prevented participants to change encoding strategy in response to the forget instruction. Future item-recognition work may examine whether the present finding of a limited enhancement effect for early List 2 items replicates with longer item presentation times or whether enhancement effects for middle and late List 2 items arise with longer item presentation times.[5]

Finding List 2 enhancement but no List 1 forgetting, the present results support two-mechanism accounts of LMDF, which assume that different mechanisms underlie the two effects of the forget cue (e.g., Pastötter & Bäuml, 2010; Sahakyan & Delaney, 2003), and challenge one-mechanism accounts, which assume that List 1 forgetting and List 2 enhancement are the two sides of the same coin and should always occur together (e.g., Geiselman et al., 1983; Sahakyan & Kelley, 2002). Doing so, the present results also challenge the selective-rehearsal account of LMDF, an older one-mechanism account of LMDF, which assumes that during List 2 encoding remember-cued participants rehearse both List 1 and List 2 items, whereas forget-cued participants selectively rehearse List 2 items only, thus improving later memory for List 2 at the expense of List 1 (Bjork, 1970). Specifically, this account assumes that the enhancement effect is largest for early List 2 items, and the forgetting effect is largest for late List 1 items, claiming that, once the forget cue is provided, (mainly late) List 1 items are deleted from the rehearsal buffer and the rehearsal starts over again with the encoding of (early) List 2 items (see Block, 1971; Bruce & Papay, 1970). While this account is consistent with the present result that List 2 enhancement in

[5]Note, however, that the results from prior recall studies indicate no such influence of item presentation rate on List 2 enhancement, showing no enhancement effects for middle and late List 2 items with presentation rates of 5 s and 6 s per item, at least when List 1 is recalled first and List 2 is recalled last (see Experiments 2 and 3 in Pastötter & Bäuml, 2010).

item recognition is restricted to early list items, it is inconsistent with the present result of no List 1 forgetting in item recognition, and it is in conflict with previous findings that reported non-selective forgetting of late List 1 items with recall testing (e.g., Pastötter & Bäuml, 2010; Pastötter et al., 2012; Sahakyan & Foster, 2009).[6]

In the literature, there is evidence that item-recognition tests are sensitive to some forms of interference, but not to others. For instance, while there are demonstrations that item-recognition tests can be sensitive to output interference (Criss, Malmberg, & Shiffrin, 2011), there is evidence that item-recognition testing may not be sensitive to proactive interference (Dennis & Humphreys, 2001; Kinnell & Dennis, 2011). The present results support the latter view. First, they show no List 2 enhancement effect for the middle and late List 2 items. According to the reset-of-encoding hypothesis, middle and late list items should not benefit from improved encoding but may show reduced proactive interference in response to the forget cue. Whereas such reduced proactive interference shows up in recall tests (Pastötter et al., 2012), following Dennis and colleagues, it may not show up in item recognition, which is consistent with the present results. Second, the present results indicate that, in item recognition, List 2 enhancement is unaffected by the two lists' testing order. This is in contrast to results from recent recall work, showing an effect of list testing order on List 2 recall enhancement, with a larger enhancement effect when List 2 is recalled first than when it is recalled last (Pastötter et al., 2012). Arguably, preceding recall of List 1 items can improve access to the List 1 study context and reinstate List 1 items' interference potential (Bäuml & Samenieh, 2010, 2012; Bjork, & Bjork, 1996), thus reducing List 2 enhancement when List 2 is recalled last. The finding that the present List 2 enhancement effect was unaffected by list testing order thus corroborates the view that the enhancement effect in item recognition reflects primarily improved encoding, and much less, if at all, reduced proactive interference.

[6]Because selective rehearsal and the reset-of-encoding hypothesis make similar predictions regarding List 2 enhancement, but only selective rehearsal and not reset of encoding, makes predictions regarding List 1 forgetting, formally one may regard the reset-of-encoding hypothesis a restrictive variant of selective rehearsal, with the goal of explaining List 2 enhancement but not List 1 forgetting.

Regarding List 1, the present results show that, on the list level, List 1 forgetting is absent in item recognition, which is consistent with the results of a large number of studies that showed exactly the same pattern of results (Benjamin, 2006; Geiselman et al., 1983; Sahakyan & Delaney, 2005; Schmitter-Edgecombe et al., 2004; Whetstone et al., 1996). In addition, the present results indicate that the forgetting is absent for all List 1 items and does not depend on list testing order. At first glance, the results may appear to be in conflict with recent work showing that, under certain conditions, List 1 forgetting can be present with recognition testing (Hanczakowski, Pasek, & Zawadzka, 2012; Lehman & Malmberg, 2009; Sahakyan, Waldum, Benjamin, & Bickett, 2009). In this recent work, however, context-recognition tests were employed that relied heavily on retrieval of item-specific context information rather than on retrieval of the item information itself. Finding reliable List 1 forgetting in such context-recognition tests indeed is consistent with the idea that List 1 forgetting is due to impaired context access (Bäuml & Samenieh, 2012; Geiselman et al., 1983; Kimball & Bjork, 2002; Sahakyan & Kelley, 2002). However, it is not in conflict with the finding that there is no List 1 forgetting in item recognition.

In sum, this study demonstrates that the presentation of a forget cue has a very limited effect on item-recognition memory in LMDF. The forget cue does not influence recognition of List 1 items and does also not influence recognition of middle and late List 2 items. In contrast, the cue enhances recognition of early List 2 items. These results support two-mechanism accounts of LMDF, which assume a critical role for a reset-of-encoding process for List 2 enhancement (Pastötter & Bäuml, 2010; Pastötter et al., 2012).

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