Does amount of precue encoding modulate selective list-method directed forgetting?

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Selectivity of list-method directed forgetting
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Abstract

Prior work reported evidence that when people are presented with both a relatively short list of relevant information and a relatively short list of irrelevant information, then a subsequent cue to forget the irrelevant list can induce successful selective directed forgetting of the irrelevant list without any forgetting of the relevant list. The goal of this study was to determine whether this selectivity effect is restricted to short lists of information (6 items per list), or whether the effect generalizes to longer lists (12 items per list). In Experiment 1, we replicated the finding that selective directed forgetting can arise when short lists of relevant and irrelevant information are employed. Going beyond this replication, we showed in Experiment 2 that such selectivity can arise both when shorter and when relatively longer lists of items are used. The results are consistent with the view that selective directed forgetting can result from the action of a flexible inhibitory mechanism. They are less well in line with the view that selective cues to forget precue information induce a change in participants’ mental context.

Keywords

episodic memory - forgetting - directed forgetting - selectivity
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A necessary prerequisite for targeted access to relevant memory content is the constant updating of the memory system (Bjork, 1989). Research over the last six decades has shown that one method by which such updating can be achieved is to deliberately forget previously learned irrelevant information. Such intentional forgetting is required in a wide variety of everyday situations, like when we learn that some study material is relevant for a later exam but other study material is not, and we want to forget the irrelevant information; or when some news we read on the internet turns out to be fake while other news appears to be credible, and we seek to forget the fake information. In the laboratory, intentional forgetting has been demonstrated using the so-called list-method directed forgetting (LMDF) task. In this task, participants are asked to study two lists of items, and, after study of the first list, are told to either keep remembering the first list for a subsequent retention test or to forget the first list under the pretense that it was for practice only. At the time of test, participants are informed that they should try to recall as many items as possible from both item lists, irrespective of original cuing. Typically, the forget cue leads to impaired memory of list 1 (precue forgetting) and improved memory of list 2 (postcue enhancement), relative to the remember condition (for reviews, see Bäuml, Pastötter, & Hanslmayr, 2010; MacLeod, 1998; Sahakyan, Delaney, Foster, & Abushanab, 2013).

During recent years, the two effects of the forget cue have mostly been explained by retrieval inhibition or context change. The retrieval-inhibition account assumes that a cue to forget the previously learned list 1 triggers active inhibitory processes that impair access to the list-1 items and, as a result of reduced interference effects from these items, lead to improved memory for list 2 (Geiselman, Bjork, & Fishman,
Alternatively, proponents of the context-change account argue that the forget cue impedes list-1 recall because such cuing alters subjects’ internal context and thus induces a mismatch between the list-1 context at encoding and the later test, and improves later list-2 recall due to the arising interference release (Sahakyan & Kelley, 2002). More current two-mechanism accounts of LMDF—which attribute the two effects of the forget instruction to distinct underlying processes—also assume that list-1 forgetting is due to either retrieval inhibition or context change (see Pastötter, Tempel, & Bäuml, 2017; Sahakyan et al., 2013).

In the standard LMDF task, all list-1 items are designated as unimportant in the forget condition, and subjects therefore are asked to forget all precue items. Doing so, previous studies in fact reported forgetting of all precue items, with similar levels of forgetting across the single list items (Pastötter & Bäuml, 2010; Pastötter, Kliegl & Bäuml, 2012; Sahakyan & Foster, 2009). Employing a variant of the standard LMDF task, however, more recent work examined whether such precue forgetting can also be selective. That is, when participants have been presented with both relevant and irrelevant precue information, are they able to forget the irrelevant precue information while keeping in mind the relevant precue information?

Selectivity of LMDF is theoretically important because different predictions can arise from different LMDF accounts. For instance, the context-change account predicts that selective LMDF should not be possible, because in response to the forget cue, an encoding-retrieval mismatch for all precue items should arise, regardless of whether the items are all to be forgotten or consist of a mixture of relevant and irrelevant information. The retrieval-inhibition account, in itself, makes no unequivocal prediction on whether or not LMDF should be selective. Prior studies demonstrating that performance in the LMDF task can be related to individuals’ working memory capacity
(Aslan, Zellner, & Bäuml, 2010; Delaney & Sahakyan, 2007; Soriano & Bajo, 2007) and executive control function (Conway & Fthenaki, 2003; Conway, Harries, Noyes, Racsmány, & Frankish, 2000; Hanslmayr et al., 2012) however indicate that retrieval inhibition constitutes a relatively flexible executive control mechanism that may be targeted in a selective way at the irrelevant precue information. If so, participants may show selective LMDF.

Research on selective LMDF examined selectivity in two experimental tasks, the 2-list task and the 3-list task. In the 2-list task, subjects are shown relevant and irrelevant items in an alternating manner within a single list (list 1), and after presentation of that list, participants are told to forget the irrelevant, but keep remembering the relevant items. Afterwards, a second list that consists of relevant items only is presented. Delaney, Nghiem, and Wiegum (2009) examined selectivity by employing short 3-word sentences and demonstrated that, while forgetting of irrelevant list-1 items arose, memory for relevant list-1 items was intact, a finding that challenges the context-change account. Four more recent studies have provided additional evidence against the context change account, by replicating this pattern of results using material that was similar to as well as different from the one employed by Delaney et al. (Aguirre, Gómez-Ariza, Andrés, Mazzoni, & Bajo, 2017; Aguirre, Gómez-Ariza, Bajo, Andrés, & Mazzoni, 2014; Gómez-Ariza et al., 2013; Kliegl, Pastötter, & Bäuml, 2013). In contrast, using the same as well as different material as Delaney et al. did, two studies (Akan & Sahakyan, 2018; Storm, Koppel, & Wilson, 2013) failed to detect any evidence of selectivity in the task, and found neither forgetting of relevant nor forgetting of irrelevant precue information.

In the 3-list task of selective LMDF, subjects study three item lists, with list 1 only consisting of relevant information and list 2 only consisting of irrelevant information.
After presentation of list 2, participants are cued to forget the irrelevant list 2 but keep remembering the relevant list 1. Subsequently, subjects are presented with a third list that only contains relevant items. Employing this type of task, Sahakyan (2004) presented participants with lists of 12 items each. After presentation of each of the three lists, subjects either received a cue to forget or keep remembering the immediately preceding list. In the R(emember)R(emember)R(emember) condition, participants were cued to remember each single list, whereas in the R(emember)F(orget)R(emember) condition, they were cued to remember list 1 and list 3, but to forget list 2. The results showed nonselective forgetting of both list 1 and list 2 in the RFR condition, which is in better agreement with the context-change than the retrieval-inhibition account. In contrast, more recent work reported evidence for selectivity in this task when employing relatively short precue lists of 6 unrelated items each (Kliegl et al., 2013). Again, there was an RRR condition, in which participants were cued to remember both list 1 and list 2, and an RFR condition, in which they were cued to forget list 2 but keep in mind list 1. Across 3 experiments, the results consistently showed evidence for selective LMDF: forgetting of list 2, but not of list 1, arose in the RFR condition, which is in better agreement with the retrieval-inhibition than the context-change account. The pattern arose independent of the modality in which the three lists had been presented in the study phase, and independent of whether the items of list 1 and list 2 were presented in the same font color or different font colors or had been read out loud by the same or different speakers.

The results from the previous studies thus are mixed and do not provide a simple yes-no answer on whether LMDF is selective or not. Rather, they may indicate that selectivity is present under some circumstances but is absent under others. Although to date it is far from clear exactly which factors induce selective and which ones induce
nonselective LMDF, the previous work may provide us with some first clues on the issue. For instance, Kliegl et al. (2013) kept material and other procedural detail constant and found equivalent selectivity in the 2-list and 3-list task of LMDF, indicating that type of task may not influence selectivity. An analogous suggestion arises for material, because selectivity in the 2-list task was reported for both sentences (Aguirre et al., in press; Delaney et al., 2009) and simple word lists (Kliegl et al., 2013).

However, the results from prior work also suggest a factor that may influence selectivity in the task, namely length of precue lists. Sahakyan (2004) used longer precue lists and found nonselective LMDF, whereas Kliegl et al. (2013) employed relatively short precue lists and found selective LMDF, suggesting that shorter precue lists may improve discriminability of lists and thus improve selectivity in LMDF (see Kliegl et al., 2013, p. 461). Because the studies by Sahakyan and Kliegl et al. show a number of methodological differences, concluding from the previous results that precue list length can modulate selectivity would be premature, however. It was therefore the primary goal of the present study to address the issue directly and examine whether length of precue lists can influence selectivity in LMDF (see Experiment 2 below). The first goal of the present study was to provide a conceptual replication of the Kliegl et al. finding that selectivity in the 3-list LMDF task can arise with short precue lists, using different word material and a different mode of item presentation as in that earlier study (see Experiment 1 below). Such an attempt appears indicated given the importance of reproducability in psychological studies (e.g., Johnson, Payne, Wang, Asher, & Mandal, 2017; Spellman & Kahneman, 2018).

**Experiment 1**

Following Experiment 2 of the Kliegl et al. (2013) study, the present Experiment 1 examined selective LMDF by comparing the effects of three cuing conditions. Subjects
were asked to study 3 lists consisting of unrelated words and, following study of list 2, were told to either keep remembering both list 1 and list 2 (RRR condition), forget both list 1 and list 2 (FFR condition), or forget list 2 but keep remembering list 1 (RFR condition). The RRR and FFR conditions served as upper and lower baselines, which allowed us to determine minimum (RRR) and maximum (FFR) forgetting of relevant and irrelevant precue information in the RFR condition. On the basis of prior LMDF work (e.g., Geiselman et al., 1983) and Experiment 2 of the Kliegl et al. (2013) study, we expected that, relative to the RRR condition, (i) memory of both precue lists would be impaired in the FFR condition - thus reflecting standard LMDF - and, more important, (ii) memory of the second precue list would be impaired but memory of the first precue list would be unaffected in the RFR condition - reflecting selective LMDF.

Method

Participants. Following Experiment 2 of the Kliegl et al. (2013) study, we tested 30 participants in each of the three experimental conditions (RRR, RFR, FFR). The ninety subjects (M = 25.0 years, SD = 7.3 years, 62 females) were recruited from Regensburg University. All participants were tested individually.

Material. Like in Kliegl et al.’s (2013) Experiment 2, 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). Different nouns were used than in the previous study. For each participant, three item lists were prepared, with lists 1 and 2 consisting of 6 items each, and list 3 consisting of 12 items. For all participants, the assignment of items to lists was random. The study material can be downloaded at https://osf.io/em75n/.

Design. The experiment had a single factor design with the between-subjects variable of cuing condition (RRR, RFR, FFR). In the RRR condition, list 2 was followed
by a cue to remember both list 2 and list 1; in the RFR condition, list 2 was followed by a cue to forget list 2 but remember list 1, in the FFR condition, list 2 was followed by a cue to forget both list 2 and list 1.

Procedure. The multiple-cue version of LMDF was used (see Pastötter & Bäuml, 2007; Zellner & Bäuml, 2006). Participants were told that they would be presented with lists of words to learn for a later recall test and that following each list, they would be given a cue to remember or forget previously studied information. Further, participants were informed that a to-be-forgotten list would not be tested on the later recall test. At the start of the experiment, the experimenter sat in front of the participant and read out loud the three lists’ items with a presentation rate of 4 sec per item. Prior to the presentation of each single list, participants were told: "I am now going to read to you list x. Please try to remember the words on the list as well as possible”. Item order within lists was random for all participants. Immediately after list-1 encoding, the experimenter asked the participant to keep remembering the list. After list-2 encoding, participants were either told to remember list 2 but keep on remembering list 1 (RRR); to forget list 2 but keep on remembering list 1 (RFR); or to forget both list 2 and list 1 (FFR). Following the encoding phase, participants counted backward from a three-digit number in steps of threes for 30 seconds as a recency control. At test, participants were asked to recall the three lists’ items, irrespective of original cuing. To control precue item lists’ output order, half of the participants were asked to recall list-1 items first and list-2 items second; for the other half, list output order was reversed. Because the focus of this study was on precue item recall, participants were asked to recall precue lists first. All participants were asked to recall list-3 items last. Participants wrote down the items of the three lists on separate unlabeled sheets of papers. Recall time for both list-1 and list-2 items was 30 sec each, whereas recall time was 60 sec for list 3.
Procedural details of the experiment were identical to Experiment 2 of the Kliegl et al. (2013) study, with the only major difference that in the present experiment, the single word lists were read aloud ‘live’ by the experimenter while, in the earlier experiment, participants heard the study lists via prerecorded audio files.

Results

Figure 1 shows mean recall rates as a function of cuing (RRR, RFR, FFR), separately for the three lists. Items were counted as recalled if recalled with the correct list. All data can be downloaded at https://osf.io/em75n/.

** Figure 1 about here **

List-1 Recall

An overall ANOVA of the three cuing conditions (RRR, RFR, FFR) showed a main effect of cuing, $F(2, 87) = 5.478$, $MSE = .063$, $p = .006$, $\eta^2 = .112$. Pair-wise comparisons showed that list-1 recall rates in the RRR condition (68.3%) were higher than in the FFR condition (50.0%), $t_{58} = 3.003$, $p = .004$, $d = .775$. In addition, recall of list-1 items in the RFR condition (68.9%) was similar to the RRR condition (68.3%), $t_{58} < 1$, but higher than in the FFR condition, $t_{58} = 3.058$, $p = .003$, $d = .800$. Like in the Kliegl et al. (2013, Experiment 2) study, these results indicate that list-1 forgetting was present in the FFR condition, but was absent in the RFR condition.

List-2 Recall

An overall ANOVA of the three cuing conditions (RRR, RFR, FFR) showed a significant main effect of cuing, $F(2, 87) = 3.331$, $MSE = .089$, $p = .040$, $\eta^2 = .071$. Pair-wise comparisons showed that list-2 recall rates in the RRR condition (64.4%) were higher than in the FFR condition (47.8%), $t_{58} = 2.578$, $p = .013$, $d = .665$, and the RFR condition (46.7%), $t_{58} = 2.092$, $p = .041$, $d = .540$. List-2 recall did not differ
between the FFR and RFR condition, $t_{58} < 1$. The findings again replicate Kliegl et al. (2013, Experiment 2), in showing that list-2 forgetting was present in both the FFR condition and the RFR condition.

**List-3 Recall**

An overall ANOVA of the three cuing conditions (RRR, RFR, FFR) showed no main effect of cuing, $F(2, 87) < 1$, again replicating Kliegl et al. (2013, Experiment 2).

**Intrusions**

Table 1 shows intrusion rates in Experiment 1, separately for the three item lists. A list’s intrusion rate represents the percentage of study items that were erroneously recalled with the wrong list. The list-1 intrusion rate, for instance, refers to the number of items from lists 2 and 3 that were falsely recalled during the test of list 1 – relative to the number of list-1 items that were presented. Three overall ANOVAs with the factor of cuing (RRR vs. RFR vs. FFR) showed no main effects, for lists 1, 2, and 3, all $F_s \leq 2.015$. Again, intrusion rates were generally low, on the order of 4% in the single conditions, independent of cuing.

**Table 1 about here**

**Discussion**

Consistent with our expectations, the results of Experiment 1 showed typical forgetting of irrelevant precue items. Indeed, when participants were asked to forget both precue lists in the FFR condition, later recall of both list 1 and list 2 was impaired; when participants were asked to forget list 2 in the RFR condition, later recall of list 2 was impaired, whereas later recall of list 1 remained intact. The results for the RFR condition thus replicate the Kliegl et al. (2013) findings, again demonstrating selective LMDF in this condition, i.e., decreased retention of irrelevant precue items and
intact retention of relevant precue items. The results of Experiment 1 challenge the context-change account, according to which forgetting of all precue information should arise. The context change after list 2 should cause a mismatch between precue encoding context and the context at test, which should reduce recall of both list 1 and list 2. In contrast, the results can be reconciled with the retrieval-inhibition account, at least under the assumption that inhibition is triggered by a flexible executive-control mechanism, as may be indicated by the results of previous studies (e.g., Aslan et al., 2010; Hanslmayr et al., 2012). If so, forgetting of the irrelevant precue items, but not the relevant precue items, may arise.

Our failure to find enhancement of the list-3 postcue items aligns with the findings of several recent LMDF studies (e.g., Delaney & Sahakyan, 2007; Zellner & Bäuml, 2006), and prior selective LMDF studies (e.g., Delaney et al., 2009; Kliegl et al., 2013, Experiments 2 and 3). Typically, the failure to observe postcue enhancement in LMDF arises when – like in the current experiment – the precue items are recalled prior to the postcue items. In fact, Pastötter et al. (2012) conducted a meta-analysis on the role of list-output order on LMDF which uncovered that the forget cue improves postcue item recall mainly when the postcue items are tested first and shows hardly any enhancement effect when the postcue items are tested last. The absence of an enhancement effect in the present experiment therefore probably arose as a result of the chosen list-output order.

**Experiment 2**

Experiment 2 examined whether selectivity in the 3-list LMDF task is affected by length of precue lists. Like in Experiment 1, we employed RRR, FFR, and RFR conditions. Again, the RRR and FFR conditions served as minimum and maximum forgetting baselines, against which recall of the relevant and irrelevant precue items in
the RFR and FRR conditions were compared. In the 6-6-12 condition, participants were exposed to relatively short precue lists, consisting of 6 items each, thus repeating the conditions employed in the Kliegl et al. (2013) study and the present Experiment 1. In contrast, in the 12-12-12 condition, participants were presented with longer precue lists, consisting of 12 items each, thus mimicking the conditions employed in the Sahakyan (2004) study. List 3 consisted of 12 items in both conditions. Following both Sahakyan (2004, Experiment 1), Kliegl et al. (2013, Experiments 1-3), and the present Experiment 1, list output order was controlled at test and participants were asked to recall the precue items first and the postcue items last.

On the basis of the findings of Kliegl et al. (2013) and our present Experiment 1, we expected that participants showed selective LMDF in the 6-6-12 condition. If so, cuing them to selectively forget list 2 should induce forgetting of the irrelevant precue list (list 2) but should not induce forgetting of the relevant precue list (list 1). On the basis of the Sahakyan (2004) finding and the hypothesis that precue list length can affect selectivity in LMDF, we expected selectivity to be reduced, or even be absent, in the 12-12-12 condition. The results of the experiment will provide direct evidence on the possible role of precue list length for selectivity in LMDF.

Method

Participants. Three-hundred and thirty-six students (M = 28.3 years, SD = 11.5 years, 201 females) at Regensburg University participated in Experiment 1. They were tested individually with 56 participants in each of the six experimental conditions. Indeed, an analysis of test power that was conducted with the GPower program (Version 3; Faul, Erdfelder, Lang, & Buchner, 2007) revealed that to detect at least a small- to medium-sized effect (f = .20; Cohen, 1988) for the critical interaction with a probability of 1 - beta = .90 and alpha = .05, 54 participants are required in each group.
Material. The same 24 unrelated German nouns as in Experiment 1 were used, but an additional 12 unrelated German nouns were drawn from the CELEX database, using the Wordgen v1.0 software toolbox (Duyck et al., 2004). Three lists of 12 words (list A, list B, list C) were created. List A and list B were further split into two sublists of 6 words each (sublists A1, A2, B1, and B2). Across lists and sublists, words were matched on frequency and word length. In contrast to Experiment 1, assignment of items to lists and sublists was constant for all participants. Lists A and B, and each of the four sublists, served exclusively and equally often as lists 1 and 2. List C always served as list 3. Each list was equally often used in the RRR condition, the RFR condition, and the FFR condition. The study material can be downloaded at https://osf.io/em75n/.

Design. The experiment had a 3 × 2 design with the between-participants factors of Cuing (RRR, RFR, FFR) and List Length (6-6-12, 12-12-12). In the RRR condition, list 2 was followed by a cue to remember both list 2 and list 1; in the RFR condition, list 2 was followed by a cue to forget list 2 but remember list 1, in the FFR condition, list 2 was followed by a cue to forget both list 2 and list 1. Regarding list length, conditions differed in the number of list-1 and list-2 items. In the 6-6-12 condition, list 1 and list 2 consisted of 6 items each; in the 12-12-12 condition, list 1 and list 2 consisted of 12 items each; list 3 always consisted of 12 items.

Procedure. The procedure was identical to that in Experiment 1, with the only exception that, at study, half of the participants were presented with short precue lists (6-6-12 condition) and the other half with long precue lists (12-12-12 condition) and, at test, recall time for both list-1 and list-2 items was 30 sec each in the 6-6-12 condition and 60 sec in the 12-12-12 condition.

Results

Figure 2 shows mean recall rates as a function of Cuing (RRR, RFR, FFR) and
list length (6-6-12, 12-12-12), separately for the three lists. Items were counted as recalled if recalled with the correct list.

** Figure 2 about here **

List-1 Recall

A $3 \times 2$ ANOVA with the factors of cuing (RRR vs. RFR vs. FFR) and list length (6-6-12 vs. 12-12-12) revealed a main effect of cuing, $F(2,330) = 14.449$, $MSE = .049$, $p < .001$, partial $\eta^2 = .081$, and a main effect of list length, $F(1,330) = 31.560$, $MSE = .049$, $p < .001$, partial $\eta^2 = .087$, but no interaction between the two factors, $F(2,330) = 1.243$, $MSE = .049$, $p = .290$, partial $\eta^2 = .007$. List-1 recall rates for the short lists were higher than for the long lists (59.5% vs. 36.9%), $t_{334} = 5.40$, $p < .001$, $d = .59$. Regarding the main effect of cuing, pair-wise comparisons showed that list-1 recall rates in the FFR condition (34.5%) were lower than in both the RRR condition (48.8%), $t_{222} = 4.791$, $p < .001$, $d = .640$, and the RFR condition (47.8%), $t_{222} = 4.116$, $p < .001$, $d = .550$; list-1 recall rates did not differ between the RFR and RRR conditions, $t_{222} < 1$. These results indicate that list-1 forgetting was present in the FFR condition but was absent in the RFR condition, for both the short and the long precue lists.

List-2 Recall

A $3 \times 2$ ANOVA with the factors of cuing (RRR vs. RFR vs. FFR) and list length (6-6-12 vs. 12-12-12) showed a main effect of cuing, $F(2,330) = 12.983$, $MSE = .063$, $p < .001$, partial $\eta^2 = .073$, and a main effect of list length, $F(1,330) = 13.894$, $MSE = .063$, $p < .001$, partial $\eta^2 = .040$, but no interaction, $F(2,330) < 1$. List-2 recall rates for the short lists were higher than for the long lists (40.0% vs. 28.8%), $t_{334} = 3.60$, $p < .001$, $d = .39$. Regarding the main effect of cuing, pair-wise comparisons showed that, compared to the RRR condition (43.1%),
list-2 recall rates were lower in both the FFR condition (32.4%), $t_{222} = 3.114$, $p = .002$, $d = .416$, and the RFR condition (26.3%), $t_{222} = 4.905$, $p < .001$, $d = .656$; list-2 recall did not differ reliably between the FFR and RFR conditions, $t_{222} = 1.825$, $p = .069$, $d = .244$. These results indicate that list-2 forgetting was present in both the FFR and RFR conditions, for both the short and the long precue lists.

List-2 Recall

A $3 \times 2$ ANOVA with the factors of cuing (RRR vs. RFR vs. FFR) and list length (6-6-12 vs. 12-12-12) showed no main effect of cuing, $F(2,330) < 1$, no main effect of list length, $F(1,330) < 1$, and no interaction between factors, $F(2,330) = 1.22$, $MSE = .05$, $p = .30$, partial $\eta^2 = .01$. Neither list length of the precue lists nor cuing affected list-3 recall.

Intrusions

Table 1 shows intrusion rates, separately for the three item lists. Three $3 \times 2$ ANOVAs with the factors of cuing (RRR vs. RFR vs. FFR) and list length (6-6-12 vs. 12-12-12) showed no main effects or interactions, for all three item lists, all $F$s $\leq 2.79$. Intrusion rates were generally low, on the order of 4% in the single conditions, independent of cuing and list length.

** Table 1 about here **

Discussion

The results of Experiment 2 show typical directed forgetting of the irrelevant precue items. In the FFR condition, cuing participants to forget the two precue lists induced forgetting of both list 1 and list 2; similarly, cuing participants to forget list 2 in the RFR condition induced forgetting of list 2. These effects were similarly present for both short and long precue lists. More important, in the RFR condition, forgetting of
(relevant) list 1 was absent for both short and long precue lists, demonstrating that selective forgetting arose and that it did not depend on precue list length. The results for the short precue lists replicate the findings of Kliegl et al. (2013) and the present Experiment 1. The results for the long precue lists extend the prior work, indicating that precue list length does not play a critical role for selectivity. The finding of selectivity for long precue lists, of course, contrasts with Sahakyan’s (2004) original failure to find selectivity for long lists, suggesting that other procedural differences between the studies may have caused the difference in results (see General Discussion). Similar to the results of Experiment 1, the results of Experiment 2 seem to be difficult to reconcile with the context-change account, but may be consistent with the retrieval-inhibition account.

General Discussion

Prior work examining selectivity in LMDF provided mixed results. Whereas in some studies, evidence for selectivity arose (Aguirre et al., 2014, 2017; Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013; Kliegl, Wallner, & Bäuml, 2018), in other studies no selectivity was reported (Akan & Sahakyan, 2018; Sahakyan, 2004; Storm et al., 2013). Moreover, one of the studies which reported nonselectivity found forgetting of both relevant and irrelevant precue information (Sahakyan, 2004), whereas two other studies reported neither forgetting of relevant nor forgetting of irrelevant precue information (Akan & Sahakyan, 2018; Storm et al., 2013). While, as a whole, these findings indicate that, under certain circumstances, LMDF can be selective, it is largely unclear to date which factors play a critical role for selectivity and which factors do not.

Against this background, it was the goal of the present study to directly examine the role of one critical factor that may influence selectivity in LMDF, namely length
of precue lists. We had hypothesized that selectivity may benefit from short precue lists and thus be present with short lists but be absent with long lists. The hypothesis was motivated by the results of previous studies which, when employing the 3-list task, found no selectivity for longer precue lists (Sahakyan, 2004) but did find selectivity for short precue lists (Kliegl et al., 2013). Employing the same precue list lengths as the two previous studies did, however, the present results did not find any evidence for a role of precue list length for selectivity in the 3-list task and rather demonstrated selectivity regardless of list length. The results of the present Experiments 1 and 2 replicate the results of Kliegl et al. (2013) for short precue lists and extend them to longer precue lists. At the same time, the results, of course, disagree with those of Sahakyan (2004), suggesting that other factors than precue list length may be responsible for the discrepancy in results.

One such factor may be control of list output order. While in the present study precue lists were always recalled first and the postcue list last, for instance, participants in Sahakyan’s (2004) Experiment 2 were allowed to recall the three lists’ items in any order they wished. Doing so, subjects in the remember condition (RRR) may have tended to recall list-1 items first, whereas subjects in the selective forget condition (RFR) may have tended to recall the postcue items first (e.g., Geiselman et al., 1983). If so, output interference may have contributed to list-1 recall in the remember condition but not in the selective forget condition and been responsible for the failure to find selectivity in the task. However, differences in output interference cannot explain all the inconsistency between studies, because in Experiment 1, Sahakyan (2004) did control for output interference, but did not find evidence for selectivity. Since comparisons between studies are generally difficult, future work should investigate the role of output order of precue and postcue lists on selective LMDF within a single experiment.
The results from recent work on selectivity in LMDF suggest two factors that may leave degree of selectivity largely unaffected. The one factor is type of LMDF task and the other factor is material. Indeed, comparing selectivity directly between the 2-list and the 3-list task, Kliegl et al. (2013) found equivalent degrees of selectivity, indicating that results from the 2-list task may generalize to the 3-list task, and vice versa. Similarly, previous studies reporting selectivity in the 2-list task used unrelated items in some studies but short sentences in others (Delaney et al., 2009; Kliegl et al., 2013), indicating that material may not play a critical role for selectivity. By demonstrating selectivity for both short and long precue lists, the present study adds amount of precue information to the list of factors that do not seem to influence selectivity in LMDF.

The present results are not easily explained by the context-change account, which claims that the forget cue induces a change in subjects’ mental context and thus impairs recall of the precue items due to a mismatch between the context at encoding and the context at test (Sahakyan & Kelley, 2002). Therefore, no selectivity should arise and both the irrelevant and the relevant precue information be subject to forgetting. The present results turned out otherwise, however, demonstrating selective forgetting of irrelevant precue information without affecting memory for the relevant precue information. The retrieval-inhibition account suggests that forget-cued participants engage in active inhibitory processes that reduce access to list-1 items (Geiselman et al., 1983). If inhibition reflected the action of a relatively flexible control mechanism (Aslan et al., 2010, Hanslmayr et al., 2012), one may expect that retrieval inhibition induces selective forgetting of irrelevant precue information, which is what the results of the present experiments show.

Recent work on the effects of prolonged retention interval on standard LMDF reported evidence that list-1 forgetting is not short-lived but is still present after delays
of 20 min or even 24 hours (Abel & Bäuml, 2017, 2019). Like the present results, this finding challenges the context-change account, because mental context change is generally assumed to create relatively transient forgetting (e.g., Divis & Benjamin, 2014; Sahakyan & Kelley, 2002). Whatever the exact mechanisms may be that underlie this forgetting (for a discussion, see Abel & Bäuml, 2019), if standard LMDF and selective LMDF were mediated by the same mechanisms, then not only standard LMDF but also selective LMDF should be lasting and the present results thus generalize to delays of at least 20 min. Persistence of selective LMDF has not been investigated to date and future work is therefore required to examine this critical prediction.

In sum, the present findings indicate that selective LMDF in the 3-list task arises not only for short lists, but also for relatively longer lists. These findings confirm and extend prior work on selectivity, which showed robust selective LMDF with short lists in both the 3-list task (Kliegl et al., 2013) and the 2-list task (Aguirre et al., in press; Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013). Overall, the findings suggest that, in many situations, people can flexibly forget a fraction of previously studied material without affecting memory of the remaining material. Theoretically, this pattern of results is hard to reconcile with the context-change account, while it is basically consistent with a retrieval-inhibition view of LMDF.

DATA AVAILABILITY

All data can be found at Open Science Framework, https://osf.io/em75n/.
REFERENCES


FOOTNOTES

1. Visual inspection of Figure 2 seems to indicate that amount of forgetting of list-2 items in the RFR condition, in comparison to the RRR condition, is more pronounced for the short precue lists than the long precue lists (list-2 forgetting: 21.1% vs. 12.5%). A 2 × 2 ANOVA with the factors of cuing (RRR vs. RFR) and list length (6-6-12 vs. 12-12-12), however, showed no interaction between the two factors, $F(1, 220) = 1.639$, $MSE = .064$, $p = .202$, $\eta^2 = .007$, suggesting that the RFR cue did not induce significantly larger forgetting for the short than the long list 2. Also note that when converted to the number of items forgotten, participants forgot about 1.27 list-2 items in the RFR condition relative to the RRR condition when short lists were used, and 1.50 list-2 items in the FFR condition relative to the RRR condition when long lists were used. Thus, regardless of how forgetting is coded, amount of list-2 forgetting appears quite comparable for short and long precue lists.
Table 1

*Mean Intrusion Rates (and Standard Errors) as a Function of CUING and LENGTH in Experiments 1 and 2.*

<table>
<thead>
<tr>
<th>List 1</th>
<th>List 2</th>
<th>List 3</th>
</tr>
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<tbody>
<tr>
<td>short</td>
<td>long</td>
<td>short</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 1</td>
<td><strong>RRR</strong></td>
<td><strong>RFR</strong></td>
</tr>
<tr>
<td>short</td>
<td>3.3 (1.5)</td>
<td>3.3 (1.9)</td>
</tr>
<tr>
<td>long</td>
<td>1.7 (1.2)</td>
<td>6.7 (2.3)</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 2</td>
<td><strong>RRR</strong></td>
<td><strong>RFR</strong></td>
</tr>
<tr>
<td>short</td>
<td>3.6 (1.2)</td>
<td>4.0 (1.2)</td>
</tr>
<tr>
<td>long</td>
<td>1.8 (0.6)</td>
<td>5.4 (1.3)</td>
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FIGURE CAPTIONS

Figure 1: Mean recall rates as a function of cuing (RRR, RFR, FFR) in Experiment 1, separately for the three item lists. RRR = participants were asked to remember all three item lists; RFR = participants were asked to remember list 1 and list 3 but to forget list 2; FFR = participants were asked to forget list 1 and list 2 but to remember list 3. Error bars represent standard errors of the mean.

Figure 2: Mean recall rates as a function of cuing (RRR, RFR, FFR) and precue list length (short, long) in Experiment 2, separately for the three item lists. RRR = participants were asked to remember all three item lists; RFR = participants were asked to remember list 1 and list 3 but to forget list 2; FFR = participants were asked to forget list 1 and list 2 but to remember list 3. Error bars represent standard errors of the mean.
Figure 1
Figure 2