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Inhibitory Deficits in Older Adults: List-Method Directed Forgetting Revisited

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In list-method directed forgetting, participants are cued to intentionally forget a previously studied list while remembering a subsequently presented 2nd list. Results from prior research are inconclusive on whether older adults show deficits in this type of task. In 3 experiments, the authors reexamined the issue and compared younger and older adults' responsiveness to the forget cue. Across the experiments, the forget cue was varied within and between participants, the 2 lists were unrelated and related to each other, and recall of the lists was required simultaneously and successively. In none of the 3 experiments did any age-related difference in directed forgetting performance emerge. List-method directed forgetting is assumed to reflect retrieval inhibition. The present results thus challenge the proposal of a general inhibitory deficit in older adults' memory performance.

Keywords: directed forgetting, inhibition, retrieval, older adults, inhibition deficit

The number of cognitive failures in daily life increases with older age. Older adults often report that they cannot remember people's names, that they have forgotten where things have been put, or that they experience difficulties finding the correct word. Senior citizens may be observed to only slowly understand the bus schedule or have trouble using a vending machine. Cognitive psychologists have made many suggestions how to explain this cognitive decline. These suggestions include the proposal of a general slowing of cognitive processing (Salthouse, 1996), reduced self-initiated processing (Craik, 1986), a reduction in recollective experience (Jacoby & Hay, 1998), or a specific deficit to build and maintain associations (Naveh-Benjamin, 2000).

A particularly prominent theory to explain reduced cognitive performance in older adults is the inhibition-deficit account (Hasher & Zacks, 1988). According to this account, effective cognitive processing presupposes that goal-relevant information is attended and, simultaneously, goal-irrelevant information is ignored. Goal-irrelevant information is assumed to be deleted from working memory or to be hindered from gaining access to working memory by means of an inhibition mechanism. If this mechanism malfunctions, working memory will be burdened with irrelevant information and task performance will decrease. Exactly this malfunctioning of an inhibitory mechanism might be the problem in older adults.

A number of findings support the inhibition-deficit account, like findings from memory and text comprehension studies. In the garden-path paradigm, for example, participants have to complete sentences in which the final word is missing but that have a highly probable ending (e.g., *She ladled the soup into her*). When participants answer with the highly probable ending (i.e., *bowl*), they are corrected by the experimenter, who offers another less probable, but nevertheless acceptable, ending (e.g., *lap*). In a later implicit memory test, younger adults usually show better memory for the experimenter-provided items than for the self-generated ones. Older adults, instead, show equal memory performance for the two types of items, indicating that they are more likely to maintain outdated information in memory (Hartman & Hasher, 1991; Hasher, Quig, & May, 1997; see also Hamm & Hasher, 1992, for related results).

Directed Forgetting: Item-Method and List-Method Task

Concerning the possible role of an inhibitory deficit in older adults' episodic memory performance, the directed forgetting paradigm has been regarded as particularly suited to examine the issue. Two directed forgetting tasks are widely used in the forgetting literature: the item-method task and list-method task. In the item-method task, participants study a list of items and the exposure of each item is followed closely by the cue either to remember it or to forget it. Usually, in a later memory task, to-be-remembered (TBR) items are better recalled than to-be-forgotten (TBF) items. By contrast, on the list-method task, participants study two lists of items. After the presentation of List 1, they receive a cue to either forget (TBF) or continue remembering this list (TBR) while studying List 2. Compared with remember-cued participants, forget-cued participants typically show impaired recall of List 1 and improved recall of List 2 items (see MacLeod, 1998, for a review of item-method and list-method directed forgetting).

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There is broad agreement in the literature that directed forgetting on the item-method task reflects differential encoding of TBR and TBF items. It is assumed that exposure of the items induces some amount of preprocessing and that further rehearsal of the item takes place only if the cue is to remember. By contrast, if the cue is to forget, precue processing is stopped and further rehearsal is suspended (Basden, Basden, & Gargano, 1993; Bjork, 1989). This stopping of processing has been argued to reflect the action of an inhibitory mechanism and to demonstrate the successful suppression of irrelevant information (Zacks, Radvansky, & Hasher, 1996), although noninhibitory explanations exist as well (Basden & Basden, 1998; MacLeod, 1998). The differential encoding account is consistent with the finding that item-method directed forgetting occurs across a wide range of memory tests and, for instance, is present in both recall and recognition tests (Davis & Okada, 1971; MacLeod, 1999; Woodward, Bjork, & Jongeward, 1973).

There is also broad agreement that directed forgetting on the list-method task manifests itself at the retrieval stage and is caused by retrieval inhibition of the TBF items. The proposal is that by inhibiting TBF (List 1) items, the forget cue reduces interference from List 1 and thus facilitates retrieval of List 2 items. Support for this inhibitory account comes from a number of findings, including studies that show that the forgetting occurs in free recall but not in recognition or implicit memory tests (Basden et al., 1993; Block, 1971; MacLeod, 1999; but see Sahakyan & Delaney, 2005) and studies that show that the forgetting extends to incidentally learned items (Geiselman, Bjork, & Fishman, 1983). However, noninhibitory accounts of list-method directed forgetting have been suggested as well (MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Sahakyan & Kelley, 2002).

Directed Forgetting in Older Adults

Evidence for deficits in older adults' directed forgetting comes mainly from studies using the item-method task. Zacks et al. (1996, Experiment 1), for instance, reported a significantly larger TBR–TBF difference for younger than for older adults, both in recall and recognition memory tests. They interpreted this result as evidence for an inhibition deficit in older adults' memory performance, arguing that contrary to the younger adults, the older adults do not stop the processing of the TBF items and thus process TBR and TBF items similarly. Larger item-method directed forgetting effects for younger adults than for older adults have also been reported in other recent work (Dulaney, Marks, & Link, 2004; Earles & Kersten, 2002), converging on the view that older adults show deficient item-method directed forgetting.

To our knowledge, there are only two published studies to date that looked at age differences in list-method directed forgetting. In the one study, Zacks et al. (1996, Experiment 2) let participants study several short lists, with each list including TBF items in the first place and TBR items in the second. Immediately after presentation of each list, participants were to recall the TBR items. After presentation of all lists, a final recall test and a final recognition test of all TBR and TBF items followed, in which larger TBR–TBF differences for younger than for older adults arose. This result is compatible with the inhibition-deficit account of cognitive aging. However, because the experiment used a nonstandard variant of the list-method task—with a cumulative recall test after learning and immediate TBR item testing of many single item lists—the result may also have been caused through certain procedural details rather than age-related inhibitory deficits. Moreover, the result was possibly affected by floor effects, as the low recall level of the older adults made it numerically impossible for them to show the same amount of forgetting as the younger adults (see the General Discussion section, below, for details).

In the second study, Sego, Golding, and Gottlob (in press, Experiment 2) followed previous work by Geiselman et al. (1983) and used a variant of the list-method task in which younger and older adults alternately learned items intentionally and incidentally. For both types of items, Sego et al. found largely identical TBR–TBF differences for the two age groups in a free-recall task, suggesting that list-method directed forgetting in older adults is intact. Because, in this experiment, a simultaneous recall task was used and subjects were free to recall the List 1 and List 2 items in any order they liked, different output sequences for TBR and TBF items may have resulted for the two age groups. Arguably, differences in output sequence may influence the amount of directed forgetting (see Golding & Gottlob, 2005), so that a reduced inhibitory function in older adults may have been "compensated" by output sequence to result in normal directed forgetting performance (see Experiment 1 below for details).

Indeed, one might like to reason that if older adults show deficient directed forgetting on the item-method task, they should show deficient forgetting on the list-method task as well. Although tempting at first glance, such a conclusion would not be warranted by data. In fact, a number of experimental dissociations between item-method and list-method directed forgetting have been identified—for example, item-method directed forgetting is present in recall and recognition tests, list-method directed forgetting is present in recall tests only—indicating that different mechanisms mediate the two types of forgetting (Basden et al., 1993; MacLeod, 1998). Thus, in principle, older adults may well show deficient directed forgetting on the one task, that is, the item-method task, and intact directed forgetting on the other, that is, the list-method task. In such a case, the interesting suggestion would arise that older adults' inhibitory capabilities depend on the task, for instance, being deficient when inhibition operates at encoding and intact when it operates at retrieval.

The results of a recent study in which older adults were found to show retrieval-induced forgetting (Moulin et al., 2002) in fact provide evidence that older adults may show intact inhibition at retrieval. *Retrieval-induced forgetting* refers to the finding that retrieval practice on a subset of studied items can impair later recall of the unpracticed material (Anderson, Bjork, & Bjork, 1994; see Anderson, 2003, for a review). Because retrieval-induced forgetting is generally assumed to be caused by retrieval inhibition (Anderson, 2003; Anderson & Spellman, 1995; Bäuml, Zellner, & Vilimek, 2005; Veling & van Knippenberg, 2004; but see Williams & Zacks, 2001, for a noninhibitory account), the results of Moulin et al. (2002) provide an example of older adults' intact inhibition at the retrieval stage. If older adults showed intact directed forgetting on the list-method task as well, then this might be evidence that older adults show intact retrieval inhibition in general.

To clarify the issue of whether older adults show a deficit in list-method directed forgetting, fresh data reasonably free of the floor effect problem are necessary that report directed forgetting effects on the standard version of the list-method task. This study addresses the question and reports the results of three traditional list-method directed forgetting experiments. In all three experiments, study conditions were arranged such that older adults' recall was essentially free of floor effects, thus allowing for a more accurate evaluation of whether older adults show an inhibitory deficit or not. Prior research examining list-method directed forgetting varied in whether the items of the two lists were required to be recalled simultaneously (Bjork, 1989; Conway, Harries, Noyes, Racsma'ny, & Frankish, 2000; Sego et al., in press) or successively (Kimball & Bjork, 2002; Sahakyan & Kelley, 2002). This study covers both methods, using simultaneous recall in Experiment 1 and successive recall in Experiments 2 and 3.

Experiment 1

The goal of Experiment 1 was to examine older adults' directed forgetting using the traditional list-method task and a simultaneous recall test. A group of young adults and a group of older adults both learned two visually presented item lists. After learning of List 1, they received either a remember or a forget cue indicating whether the so-far-seen items had to be remembered or to be forgotten. After learning, participants were asked to recall all previously learned items independent of the cue in the study phase. Recall of List 1 and List 2 items was simultaneous. Each participant learned two sets of lists, one set in the remember condition and the other in the forget condition.

An inhibitory deficit in older adults will be indicated if, compared with the young adults, the older adults showed reduced forgetting of the TBF items, or showed no forgetting at all. Such a result would support the view of an inhibitory deficit in older adults' list-method directed forgetting. If, however, the older adults showed the same directed forgetting pattern as the younger adults, then this result would be consistent with the proposal that the inhibitory mechanism underlying list-method directed forgetting is intact in older adults. Such a result might indicate that older adults show intact retrieval inhibition in general.

Method

Participants. Eighteen young and 18 older adults participated in the experiment. The older adults had a mean age of 72.6 years ($SD = 6.0$; range = 63–81) and 11.2 years ($SD = 1.1$) of formal education. They were recruited from the community. The young adults had a mean age of 21.3 years ($SD = 2.2$; range = 19–27) and each of them had at least 13 years of formal education. Through their participation in the experiment, the young adults fulfilled requirements for exam admission. All of the participants in this experiment reported being in good health and having good hearing and vision.

To test general intelligence and cognitive capacity of the older adults, we used two subtests of the German version of the Hamburg–Wechsler–Intelligence Test—Revised (HAWIE–R; Tewes, 1991), the vocabulary subtest and the digit span subtest. On the vocabulary subtest, older adults reached a score of 22.7 ($SD = 5.1$; range = 9–30), on the digit span subtest they reached a score of 16.6 ($SD = 2.9$; range = 10–21). Corresponding data for the younger adults were not available (but see Experiment 2 for data of a comparable subject group).

Materials. The item material consisted of four lists of 12 unrelated items each. Items were concrete nouns of two or three syllables chosen from the word norms of Mannhaupt (1983) and Scheithe and Bäuml (1995). Each item belonged to a different semantic category within these norms. The assignment of items to lists was constant for all participants. Item order within lists was also constant. Each list was equally often used in the remember condition and in the forget condition and served equally often as the first or the second presented list.

Design. We used a $2 \times 2 \times 2$ design with the between-participants factor age group (younger adults vs. older adults) and the within-participants factors condition (remember vs. forget) and list (List 1 vs. List 2). Conditions differed only in the interlist cue, which stated in the remember condition that List 1 should be remembered and in the forget condition that List 1 should be forgotten. Order of conditions was counterbalanced across participants.

Procedure. Participants were informed about the general nature of the experiment. They were told that they had to learn some items and that their memory for these items would later be tested. They were also told that it could happen that, just after presentation, the experimenter would declare an item list as no longer relevant and that, in this case, they should try to forget the related list. A short practice trial with a forget cue followed.

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, to their surprise, told to remember the forget items. Participants who completed the forget condition first and the remember condition second were confronted with the surprise test after their first trial. In this case, the experimenter assured firmly that she would not deceive the participant again. Pilot experiments in our laboratory indicated that list-method directed forgetting experiments lead essentially to the same results, independent of whether each participant accomplishes both the remember and the forget condition or accomplishes just one of the two conditions (see Experiment 3 below for an examination of list-method directed forgetting using the more traditional between-participants design).

Items were shown on index cards with a presentation rate of one item every 3 s. After the last item of the first list was shown, a cue was given, which varied dependent on condition. In the remember condition, participants were cued to continue to remember the so-far-seen items and to additionally learn another list. In the forget condition, participants were told that the so-far-seen items would not be tested later and that they therefore should try to forget these items and instead learn another list. Then, the second list was presented in the same way as the first one. A distracter phase followed in which participants had to solve some simple math problems for 2 min. In the test phase, all presented items regardless of the original cue had to be remembered. Participants in the forget condition were explicitly told that the forget cue in the study phase was only for pretence. Participants were free to recall the items in any order they wished. They named the items aloud and the experimenter noted their answers. There was a break of 5 min between a participant's remember and forget condition.

Results

Following recent work on directed forgetting in which it has been argued that different mechanisms may mediate the effects of the forget cue on List 1 and List 2 performance (Sahakyan & Delaney, 2003), we analyzed List 1 and List 2 performance separately. Table 1 shows the results.

Concerning List 1, younger adults recalled 48.6% of the items in the remember condition and 32.4% in the forget condition. Older adults recalled 24.5% of the items in the remember condition and 13.0% in the forget condition. A 2×2 analysis of variance with the between-participants factor of age group (older adults vs. younger adults) and the within-participants factor of condition (remember vs. forget) showed a significant main effect of age, $F(1, 34) = 40.3$, $MSE = .021$, $p < .001$, and a significant main effect of condition, $F(1, 34) = 12.1$, $MSE = .029$, $p < .001$. These main effects reflect the higher overall recall performance of the younger

Table 1
Recall Percentage (and Standard Error) of List 1 and List 2 Items in Experiment 1

	Younger adults		Older adults	
Condition	List 1	List 2	List 1	List 2
Remember	48.6 (4.0)	45.3 (3.5)	24.5 (2.8)	17.1 (3.2)
Forget	32.4 (4.7)	53.2 (4.5)	13.0 (3.0)	28.7 (2.5)

adults and the lower recall levels in the forget condition. The interaction between the two factors was not significant, $F(1, 34) < 1.0$, indicating that the forget instruction had the same negative effect on List 1 performance in the two participant groups.

Younger adults' recall performance for the List 2 items was 45.3% in the remember condition and 53.2% in the forget condition. Older adults' recall performance was 17.1% in the remember condition and 28.7% in the forget condition. A 2 × 2 analysis of variance with the between-participants factor of age group (older adults vs. younger adults) and the within-participants factor of condition (remember vs. forget) yielded a significant main effect of age group, $F(1, 34) = 45.3$, $MSE = .028$, $p < .001$, and a significant main effect of condition, $F(1, 34) = 10.1$, $MSE = .017$, $p < .01$. These main effects reflect the higher overall recall performance of the younger adults and the higher recall levels in the forget condition. The interaction between condition and age group was not significant, $F(1, 34) < 1.0$. The forget instruction thus had the same positive effect on List 2 performance in the two participant groups.

Discussion

To the best of our knowledge, this is the first reported experiment in which directed forgetting in older adults was examined using the standard version of the list-method task. Both the young adults and the older adults showed the typical pattern of directed forgetting with reduced recall of List 1 items and enhanced recall of List 2 items. Besides this qualitative parallel, the results for the older adults also did not differ quantitatively from the younger adults' performance. This holds both for List 1 and List 2 recall. These results are consistent with the view that, in the traditional list-method task of directed forgetting, older adults show intact inhibition.

There is a slight tendency in the data of Experiment 1 that older adults show reduced forgetting of TBF items (see Table 1). Although far from significant, this tendency may arguably be indicative of a slightly deficient inhibitory mechanism in older adults' directed forgetting. If true, this deficiency should show up more clearly under conditions in which inhibition is harder to accomplish in list-method directed forgetting than it was in Experiment 1. In Experiment 1, lists consisted of unrelated items with only weak item-to-item associations, both within and across lists. There is evidence that inhibition in the list-method task is harder to accomplish if the two sets of items show some degree of semantic relatedness than if they are unrelated (Conway et al., 2000; see also Golding, Long, & MacLeod, 1994, and Zacks et al., 1996, Experiment 1, for related results concerning the item-method task). Introducing some degree of semantic relatedness across lists thus may lead to a more sensitive test of whether older adults show an age-related deficiency in inhibitory function. To increase chances to detect such age-related differences, in Experiment 2 we therefore used semantically related lists.

In Experiment 1, participants were free to recall the List 1 and List 2 items in any order they liked. To the extent the forgetting cue was successful, this noncontrol of output order may have lead to different output sequences in the remember and forget condition, with the (stronger) TBR items being recalled prior to the (weaker) TBF items in the forget condition (Wixted, Ghadisha, & Vera, 1997). *Output interference* refers to the observation that recall performance declines for items remembered later in the testing sequence (Bäuml, 1998; Bäuml & Hartinger, 2002; Smith, 1971; Roediger, 1973). Thus, in the forget condition, more output interference may have resulted for List 1 items than in the remember condition, which would add to the effect of the forget cue itself (see Golding & Gottlob, 2005).

If older adults were less responsive to the forget cue than younger adults—and thus showed deficient inhibition (Zacks et al., 1996)—but were more susceptible to output interference effects than the younger adults, then the two age groups might show the same amount of directed forgetting on this task, although differing in inhibitory function. To exclude this possibility as an explanation of the results of Experiment 1, in Experiment 2 we controlled for output order and participants were required to recall the two lists successively rather than simultaneously.

Experiment 2

The goal of Experiment 2 was to replicate the results of Experiment 1 under conditions which provide a more direct and possibly stronger test of the proposal that older adults show an inhibition deficit in list-method directed forgetting. To reach this goal, two methodological modifications were made. The one modification was that lists were used that were semantically related to each other rather than unrelated. This modification may make inhibition of List 1 items harder and may thus increase chances to find age-related differences in inhibitory function.

The other modification was that recall order was controlled and half of the participants recalled List 1 items first and the other half recalled List 2 items first (Kimball & Bjork, 2002). Examining List 1 and List 2 performance in this way permits an analysis of directed forgetting, which controls for possible output interference effects. In this way, we come up with a more direct test of the proposal that older adults show deficient directed forgetting. As a further difference to Experiment 1, the items of the two lists were presented auditorily rather than visually, and a different forget cue was used than in Experiment 1.

Again, on the basis of the inhibition-deficit hypothesis, older adults should show less directed forgetting than younger adults, or show no forgetting at all, thus supporting the view that with increasing age the inhibitory function gets deficient. On the basis of the results of Experiment 1 and the assumption that older adults show the same susceptibility to output interference effects as younger adults, instead, one might expect to find the same pattern of directed forgetting in younger and older adults, suggesting that older adults show no inhibitory deficit in this type of task.

Method

Participants. Twenty-four younger and 24 older adults took part in the experiment. The younger adults were students at the University of Regensburg, Regensburg, Germany, and were paid for participation. Their mean age was 22.6 years ($SD = 2.4$; range = 19–28 years) and they had 15.4 years ($SD = 1.3$) of formal education on average. The older adults were recruited from the community of Regensburg. Their mean age was 71.2 years ($SD = 5.8$; range = 62–80) and they had 11.6 years ($SD = 1.7$) of formal education on average. The difference in education level between the younger and the older adults was significant, $t(46) = 8.6$, $p < .001$. All participants in this experiment reported being in good health and having good hearing and vision.

Scores from the vocabulary and the digit span subtests of the HAWIE–R were collected for all the participants. The vocabulary score was significantly higher for the younger adults (M = 25.0, $SD = 2.4$; range = 20–28) than for the older adults (M = 21.9, $SD = 3.8$; range = 14–30), $t(46) = 3.4$, $p < .001$. In the digit span subtest, the opposite pattern arose and the younger adults (M = 14.5, $SD = 3.1$; range = 9–22) tended to score lower than the older adults (M = 16.3, $SD = 3.0$; range = 10–25), $t(46) = 2.0$, $p = .06$.[1]

Materials. Item lists were constructed from first association norms for adults (Hasselhorn & Grube, 1994). Two cue words from each of four semantic categories (“animals,” “tools,” “body parts,” and “furniture”) were chosen and, for each cue word, the 10 most common first associates were taken for the item list. For instance, from the category “furniture,” the two cue words *armchair* and *oven* were chosen. The 10 most common first associates to *armchair*, according to the norms, were *sofa*, *pillow*, *coziness*, *sleep*, *grandma, televisions*, *cushion*, *blanket*, *rest*, and *armrest*. The 10 most common first associates to *oven* were *warmth*, *stovepipe*, *wood*, *heater*, *fire*, *coal*, *winter*, *cooker*, *heat*, and *soot*. The two lists were similar to each other because all the items were associates of pieces of furniture. Comparable item material was also used in the studies by Kimball and Bjork (2002) and Zellner and Bäuml (2005). Constructing the lists in this way, we received four pairs of lists with 10 items each. Each single participant saw two pairs of lists, one in the remember condition and one in the forget condition. Lists were recorded on audio CD with a constant item order according to association strength beginning with the strongest associate. Cue words were not provided.

Design. The experiment followed the traditional list-method directed forgetting design as described in Experiment 1, with the additional between-participants factor of test order (List 1 tested first vs. List 2 tested first). As in Experiment 1, we examined age group (younger vs. older adults) as a second between-participants factor and condition (remember vs. forget) and list (List 1 vs. List 2) as within-participants factors. Order of conditions was balanced across participants. Half of the participants started with the remember condition, and the other half started with the forget condition. Within a particular condition, a pair of lists was provided, one as List 1 and the other as List 2. Both lists consisted of associates to cue items that came from the same semantic category. Each participant heard two pairs of lists in the experiment, one pair in the forget condition and one pair in the remember condition. Each list pair was equally often used in the forget and in the remember condition. Each list within a list pair was equally often used as List 1 and as List 2.

Procedure. The procedure was largely identical to the one used in Experiment 1. The main difference was that this time participants were presented the words auditorily rather than visually. Indeed, from an audio CD, a male voice spoke the items in a rate of one item every 2 s. After presentation of the List 1 items, the experimenter stopped the CD and gave the interlists cue dependent on condition. In the forget condition, the experimenter pretended that she had inadvertently played the wrong list and that the participant should try his best to forget the list. She would now play the correct list which definitively should be remembered. To enhance credibility, the experimenter then changed the CD. In the remember condition, the experimenter said that the so-far-heard items were just the first part of the task and that another list would follow, which should also be remembered.

After presentation of List 2, participants solved simple math problems as a distracter task for 2 min. To avoid a ceiling effect that was apparent in a pilot study, the younger adults received a prolonged distracter phase of 5 min of solving math problems. At the end of the distracter phase, participants were told to remember the items. Output order was balanced. Half of the participants were first asked to remember only items from the second CD they had heard. When no more List 2 items could be remembered, participants recalled the items from the first CD. For the other half of participants, the order was reversed. The recall period for each list was at least 1 min. If a subject indicated that he or she would need additional time to recall a list’s items, the recall period was prolonged. Participants recalled the items orally and the experimenter took notes. There was a break of 5 min between a participant’s remember and forget condition.

Results

Counting of correctly recalled items was continuously liberal. That is, items were counted as correctly recalled if they were named at any time during the test phase, provided that they were part of the current condition’s lists. Overall, less than 1% of items were recalled with the wrong list, which is consistent with prior research (Sahakyan & Delaney, 2003). Recall percentages are shown in Table 2.

Concerning List 1, on average, younger adults recalled 65.8% of the items in the remember condition and 55.0% in the forget condition. In the remember condition, 65.0% of the items were recalled when tested first and 66.7% when tested second; in the forget condition, recall performance was 54.2% when tested first and 55.8% when tested second. Older adults, on average, recalled 46.3% of the items in the remember condition and 33.3% in the forget condition. In the remember condition, 43.3% of the items were recalled when tested first and 49.2% when tested second; in the forget condition, recall performance was 27.5% when tested first and 39.2% when tested second.

A $2 \times 2 \times 2$ analysis of variance with the between-participants factor of age group (older adults vs. younger adults), the within-participants factor of condition (remember vs. forget), and the between-participants factor of test order (List 1 tested first vs. List 2 tested first) was conducted. The analysis yielded a significant main effect of age, $F(1, 44) = 23.1$, $MSE = .044$, $p < .001$, indicating that older adults generally recalled fewer List 1 items than younger adults, a significant main effect of condition, $F(1, 44) = 12.1$, $MSE = .028$, $p < .001$, reflecting the expected forgetting of List 1 items in the forget condition, but no significant main effect of test order, $F(1, 44) = 1.5$, $MSE = .044$, $p > .20$. The interaction between the two factors of age and condition was not significant, $F(1, 44) < 1.0$, suggesting that the amount of forgetting did not vary with age group. There was also no significant interaction between test order and the other two factors of age and condition, all $F(1, 44)$s < 1.0.

[1] In Experiments 1 and 2, we tried to exclude a situation in which the possible inefficient inhibition of older adults was confounded with low cognitive functioning. As a result, we screened for moderate and high diagnostic values in our older adults’ samples, which may be responsible for the relatively high digit span values found for the older adults in these two experiments. In Experiment 3, described below, we abandoned this prior screening.

Table 2
Recall Percentage (and Standard Error) of List 1 and List 2 Items in Experiment 2

	Younger adults		Older adults	
Condition	List 1	List 2	List 1	List 2
Overall				
Remember	65.8 (2.7)	61.7 (3.2)	46.3 (4.0)	52.9 (4.1)
Forget	55.0 (4.5)	60.8 (2.9)	33.3 (4.1)	50.8 (5.1)
List 1 first				
Remember	65.0 (4.8)	58.3 (4.9)	43.3 (6.4)	51.7 (5.9)
Forget	54.2 (7.1)	59.2 (3.6)	27.5 (5.9)	45.8 (6.9)
List 2 first				
Remember	66.7 (2.6)	65.0 (4.0)	49.2 (4.8)	54.2 (6.0)
Forget	55.8 (5.7)	62.5 (4.6)	39.2 (5.3)	55.8 (7.5)

Concerning List 2, on average, younger adults' recall performance was 61.7% in the remember condition and 60.8% in the forget condition. In the remember condition, 65.0% of the items were recalled when tested first and 58.3% when tested second; in the forget condition, recall performance was 62.5% when tested first and 59.2% when tested second. Older adults, on average, recalled 52.9% of the items in the remember condition and 50.8% in the forget condition. In the remember condition, 54.2% of the items were recalled when tested first and 51.7% when tested second; in the forget condition, recall performance was 55.8% when tested first and 45.8% when tested second.

A 2 $\times$ 2 $\times$ 2 analysis of variance with the between-participants factor of age group (older adults vs. younger adults), the within-participants factor of condition (remember vs. forget), and the between-participants factor of test order (List 1 tested first vs. List 2 tested first) was conducted. Neither a significant main effect of condition, $F(1, 44) < 1.0$, nor a significant main effect of test order, $F(1, 44) = 1.5$, $MSE = .051$, $p > .20$, arose. There was a significant main effect of age, however, $F(1, 44) = 4.1$, $MSE = .051$, $p < .05$, indicating that older adults generally recalled fewer List 2 items than younger adults. None of the interactions reached significance, all $F(1, 44)$s < 1.0.

Discussion

The goal of Experiment 2 was to provide a somewhat stronger and more direct test of the proposal that older adults show deficient inhibition in list-method directed forgetting. Therefore, we used semantically related items and controlled for possible output order effects. Essentially the same results arose as in Experiment 1. Both the young adults and the older adults showed reduced recall of List 1 items, thus demonstrating effective directed forgetting. Moreover, the amount of forgetting did not differ significantly between the two age groups. If anything, the forgetting was slightly larger for the older than for the younger adults. Again, the results suggest that in the traditional list-method task of directed forgetting, older adults show intact inhibition.

One might have expected that the directed forgetting effect on List 1 recall increases if List 2 items are recalled before List 1 items. In such a case, the observed forgetting effect would not only mirror the effect of the forget cue but include an output interference effect as well. In the present study, this issue is important, as younger and older participants might not only differ in their responsiveness to the forget cue but differ in their susceptibility to output interference effects as well. Moreover, the two age effects might cancel each other, causing equal amounts of directed forgetting despite differences in inhibitory function. As it turned out, however, testing order did not affect the present results, indicating that output interference did not contribute to the observed forgetting effect and did also not contribute to the observed forgetting in Experiment 1.[2]

As opposed to Experiment 1, in the present experiment, the forget cue influenced List 1 recall but did not influence List 2 recall. This holds for both the younger and the older adults. Such a pattern of reduced List 1 recall and unaffected List 2 recall has been reported repeatedly in the literature (Conway et al., 2000; Sahakyan & Delaney, 2003) and has also been found in several experiments in our own laboratory. Why exactly some experimental conditions make the forget cue affect List 1 and List 2 performance, whereas others lead to an effect on List 1 performance only, is still a challenge. An explanation may arise from a recent suggestion by Sahakyan and Delaney (2003), who argued for different mechanisms underlying the effect of the forget cue on List 1 and List 2 recall. Regarding the effect on List 2, they proposed that the recall improvement emerges because the forget cue increases the likelihood that participants will adopt a better study strategy on List 2 compared with the remember cue. Consistently, when participants were instructed to encode both lists using the same study strategy, Sahakyan and Delaney found no improvement in List 2 recall (see also Sahakyan & Delaney, 2005). Whatever the right explanation for the varying effect of the forget cue on List 2 recall may be, it is important to note that, like in Experiment 1, in Experiment 2 the forget cue did not affect younger and older adults' List 2 performance differently.

Experiment 3

Directed forgetting is typically examined using a between-participants design in which half of the participants receive the remember cue and half the forget cue. Experiments 1 and 2 differ in this respect from prior research. These experiments examined younger and older adults' directed forgetting using a within-participants design in which each participant took part in both the

[2] There is a slight tendency in the data of Experiment 2 that List 2 items were recalled best if they were recalled first, and List 1 items were recalled best if they were recalled second. This pattern may be indicative of a preference in participants' output order, favoring testing conditions in which List 2 items have to be recalled first and List 1 items second. Though potentially interesting, this tendency for an output order preference did not reach significance.

remember and the forget condition.[3] Pilot data in our own laboratory indicated that directed forgetting performance does not vary whether a between-participants or a within-participant design is used, at least in younger adults. To address the issue more thoroughly and to include older adults' performance as well, in Experiment 3 we reexamined older adults' list-method directed forgetting using the more traditional between-participants design. Besides, Experiment 3 is essentially a replication of Experiment 2 with the only other exception that, at test, List 1 was always tested prior to List 2 (Sahakyan & Kelley, 2002). Choosing such an output order again controls for possible output interference effects in the two participant groups' List 1 performance and thus allows a more direct test of the inhibitory deficit proposal.

Method

Participants. Forty-eight older adults and 48 younger adults participated in this study. The older adults were recruited from the community and had a mean age of 69.8 years (*SD* = 6.2; range = 60–83) and 13.7 years of education (*SD* = 3.6) on average. The younger adults had a mean age of 23.0 years (*SD* = 2.7; range = 19–32) and 15.8 years of education (*SD* = 1.7). The difference in education years between younger and older adults was significant, $t(94) = 3.7$, $p < .001$. All participants in this experiment reported being in good health and having good hearing and vision.

To assess general cognitive capacity, we administered two diagnostic tests. In the digit span subtest of the HAWIE–R, the older adults achieved a mean score of 13.2 (*SD* = 3.5; range = 6–23) and the younger adults a mean score of 16.9 (*SD* = 3.5; range = 8–24). This difference between the age groups was significant, $t(94) = 5.1$, $p < .001$. Further, to test general intelligence, we administered the Mehrfachwahl-Wortschatz-Intelligenztest (MWT-A; multiple choice-vocabulary-intelligence test) (Lehrl, 1991), which measures adults' crystallized intelligence. The older adults achieved a mean score of 32.4 (*SD* = 2.7; range = 26–36), the younger adults a mean score of 31.2 (*SD* = 2.6; range = 25–37). This difference between the age groups was also significant, $t(94) = 2.2$, $p < .05$.

Materials. Two pairs of lists were taken from the material used in Experiment 2. Each participant saw one pair of lists.

Design. We used a between-participants design in which half of the participants were tested in the remember condition and the other half were tested in the forget condition. The older adults participating in the remember condition did not differ in age from those participating in the forget condition (69.3 years vs. 70.3 years; $t(46) < 1$). The between-participants factor age group and the within-participants factor list were studied as in Experiments 1 and 2.

Procedure. The procedure of Experiment 3 was identical to the procedure of Experiment 2, with the only exception that test order was constant for all participants and participants always recalled List 1 items before List 2 items.

Results

Like in Experiment 2, counting of correctly recalled items was liberal. Items were counted as correctly recalled if they were named at any time during the test phase. Again, overall, less than 1% of items were recalled with the wrong list. Recall percentages are shown in Table 3.

Table 3
Recall Percentage (and Standard Error) of List 1 and List 2 Items in Experiment 3

Condition	Younger adults List 1	Younger adults List 2	Older adults List 1	Older adults List 2
Remember	70.8	62.9	45.4	37.1
	(2.6)	(3.2)	(3.9)	(3.7)
Forget	58.8	69.6	27.9	50.4
	(3.3)	(2.7)	(3.0)	(3.6)

Concerning List 1, younger adults recalled 70.8% of the items in the remember condition and 58.8% in the forget condition. Older adults recalled 45.4% of the items in the remember condition and 27.9% in the forget condition. We conducted a 2 × 2 analysis of variance with the two between-participants factors of age group (younger vs. older adults) and condition (forget vs. remember). The analysis revealed a significant main effect of age group, $F(1, 92) = 75.2$, $MSE = .025$, $p < .001$, and a significant main effect of condition, $F(1, 92) = 20.8$, $MSE = .025$, $p < .001$. Younger adults recalled more items than older adults, and more items were recalled in the remember than in the forget condition. The interaction between the factors of age group and condition was far from significance, $F(1, 92) < 1.0$, indicating that the amount of forgetting did not differ between the two age groups.

Concerning List 2, younger adults' recall performance was 62.9% in the remember condition and 69.6% in the forget condition. Older adults' recall performance was 37.1% in the remember condition and 50.4% in the forget condition. We conducted a 2 × 2 analysis of variance with the two between-participants factors of age group and condition. The analysis yielded a significant main effect of age group, $F(1, 92) = 46.2$, $MSE = .026$, $p < .001$, and a significant main effect of condition, $F(1, 92) = 9.1$, $MSE = .026$, $p < .001$. Again, younger adults recalled more items than older adults. This time, however, more items were recalled in the forget than in the remember condition. The interaction between the two factors was not significant, $F(1, 92) = 1.0$. The facilitatory effect of the forget cue, therefore, did not differ between the two age groups.

To increase statistical power when testing for the critical age-interaction in List 1 and List 2 recall, we pooled the data of the three experiments. Concerning List 1, mean recall for the younger adults was 61.9% in the remember condition and 49.9% in the forget condition; for the older adults, it was 40.0% in the remember condition and 25.8% in the forget condition. A 2 × 2 analysis of variance revealed a significant main effect of age, $F(1, 260) = 92.5$, $MSE = .038$, $p < .001$, and a significant main effect of condition, $F(1, 260) = 30.1$, $MSE = .038$, $p < .001$, but no significant interaction between the two factors, $F(1, 260) < 1.0$. These results mirror those from the separate analyses reported in Experiments 1–3 above.

Concerning List 2, mean recall for the younger adults was 57.5% in the remember condition and 61.8% in the forget condi-

[3] The present within-participants design—in which each participant takes part in both a remember cue and a forget cue condition—differs from another within-participants design in which each participant takes part in a forget cue condition only. In this latter case, the goal is to examine an individual's performance on a (first) forget list compared with a (second) remember list (see MacLeod, 1998, p. 5, for details).

tion; recall for the older adults was 37.4% in the remember condition and 44.6% in the forget condition. A 2 × 2 analysis of variance revealed a significant main effect of age, $F(1, 260) = 60.0$, $MSE = .038$, $p < .001$, and a significant main effect of condition, $F(1, 260) = 5.7$, $MSE = .038$, $p < .05$, but no significant interaction between the two factors, $F(1, 260) < 1.0$. Again, these results mirror those from the separate analyses reported in the single experiments.

Most of the studies on directed forgetting in younger adults have reported detrimental effects of the forget cue on List 1 recall between 10% and 20% (e.g., Conway et al., 2000; Kimball & Bjork, 2002; Sahakyan & Kelley, 2002; see Tables 1–3 for comparable results in the present study). Taking the standard deviations reported in these studies into account, this forgetting leads to effect sizes on the order of $d = .625$, and higher. According to Cohen's (1988) effect size conventions, the typical directed forgetting effect on List 1 performance thus shows a moderate to large effect size. On the basis of this convention, we conducted a power analysis for the pooled data of the three experiments. Given a total sample size of 264 and an alpha level of .05, over all three experiments a (moderate) interaction effect size of 0.25 (cf. Cohen, 1988) could be detected with a probability of $(1 - \beta) = .98$ and a (large) interaction effect of size 0.40 could be detected with a probability of $(1- \beta) = 1.0$.[4]

Discussion

The goal of Experiment 3 was to replicate the results of Experiment 1 and Experiment 2 using the more traditional between-participants design of list-method directed forgetting and testing List 1 items always before List 2 items. Choosing this output order controls for possible output order effects with regard to List 1 performance and thus rules out an output interference explanation of the forgetting results. With regard to List 1 recall, exactly the same results arose as in the previous Experiments 1 and 2 and both groups showed significant forgetting of List 1 items. With regard to List 2 recall, the same result arose as in Experiment 1 and both groups showed significant improvement in their List 2 recall. For both lists, the two age groups differed neither in pattern nor in size. If anything, the older adults showed slightly more forgetting of List 1 items and slightly more recall improvement of List 2 items.

The results of Experiment 3 support the findings from Experiments 1 and 2 and are consistent with the proposal that older adults show intact inhibition in the list-method task of directed forgetting. The results also indicate that list-method directed forgetting can be studied both when using the traditional between-participants design and when using the present within-participants design in which each participant takes part in both the remember and the forget condition. This finding is of potential relevance for future directed forgetting experiments, as it offers a more parsimonious method to study this form of episodic forgetting.

General Discussion

Across three experiments, we examined older adults' directed forgetting using the standard version of the list-method task. In all three experiments, the forget cue reduced List 1 recall of the two participant groups, with the amount of forgetting being the same in younger and older adults. Such a pattern arose both when varying the forget cue within participants and when varying it between participants; it arose when the two lists were unrelated and when they were related; and it arose when recall of the two lists was simultaneous and when it was successive.

Supplementing the picture, younger and older participants did also not differ in the effect of the forget cue on List 2 recall. In Experiments 1 and 3, the two participant groups showed the same recall enhancing effect of the forget cue; in Experiment 2, both groups showed no effect of the forget cue on List 2 recall at all. Thus, in none of the three experiments did any age-related difference in the directed forgetting performance emerge, neither with respect to List 1 nor with respect to List 2 performance. These results suggest that older adults show intact inhibition in the list-method task of directed forgetting.

Relation to Previous List-Method Findings

The present results disagree with the results from the previous study by Zacks et al. (1996, Experiment 2). Zacks et al. used a nonstandard variant of the list-method task and found reduced forgetting in older adults' recall performance. The question arises regarding what caused the difference between this previous experiment and the present series of experiments. At least two possibilities arise. The one possibility is that the two studies differed in important aspects of their older adults participant group. The other possibility is that important procedural differences exist between the traditional list-method task and the variant which was used in the Zacks et al. study, which might have caused the difference.

The first question to answer is whether the present finding that older adults show intact directed forgetting might have benefited from the choice of our participant group. Were our older adults younger or better educated, or did they have a better intellectual functioning than the older adults in the Zacks et al. (1996) study? Taking all three present experiments into account, we do not see evidence for such differences. The general intellectual functioning in our study was not higher than in comparable studies of cognitive aging. In particular, Zacks et al.'s participants were not older or less educated or lower in intelligence scores than our participants were. Whereas the older adults in the Zacks et al. study tended to show higher diagnostic scores than the younger adults, the older adults in our study, at least in Experiment 3, tended to show lower scores than the younger adults.

Because Zacks et al. (1996) did not use the standard version of the list-method task, a number of procedural differences exist between their study and the present one. Possibly the most important procedural difference is the testing procedure. Zacks et al.

[4] We also conducted separate power analyses for the Experiments 1 through 3. In Experiments 1 and 2, given total sample sizes of 36 and 48 and an alpha level of .05, a (moderate) interaction effect of size (F^2) .15 (cf. Cohen, 1988) could be detected with a probability of .62 in Experiment 1 and .75 in Experiment 2. A (large) interaction effect of size (F^2) .35 could be detected with a probability of .93 in Experiment 1 and .98 in Experiment 2. In Experiment 3, given a total sample size of 96 and an alpha level of .05, a (moderate) interaction effect of size 0.25 (cf. Cohen, 1988) could be detected with a probability of .68. A (large) effect of size 0.40 could be detected with a probability of .97. All the power calculations reported in this paper were conducted using the GPower program (Erdfelder, Faul, & Buchner, 1996; Faul & Erdfelder, 1992).

based their conclusion on a cumulative recall test conducted after learning and immediate TBR item testing of many single item lists. Because of this testing procedure, participants received additional practice trials on the TBR items. If younger adults benefited more from these practice trials than older adults, this practice may have increased the young–old difference on the final recall test. Such a practice effect might also explain why Zacks et al. observed directed forgetting on the final recognition test, which disagrees with the results from most prior work (see MacLeod, 1998).

Still another possible reason for the difference in recall performance across the two studies is the floor effect that is present in the Zacks et al. (1996) study and that seems to carry the brunt of the age effect. For the young adults, Zacks et al. found a recall performance of 12.4% for the TBR items and 4.1% for the TBF items. For the older adults, Zacks et al. found a recall performance of 6.1% for the TBR items and 3.6% for the TBF items. Obviously, because of their low recall level, it would have been numerically impossible for the older adults to show the same amount of forgetting as the younger adults. By contrast, the data of the present experiments were free of floor effects and left enough room for older participants to show the same amount of forgetting as the younger participants. Under such conditions, no evidence for an inhibitory deficit arose.

The present results are consistent with those from the recent study by Sego et al. (in press, Experiment 2), who reported identical TBR–TBF differences for the younger and older adults in a free-recall task. Because Sego et al. used a simultaneous recall task, their experiment parallels the present Experiment 1. This holds even though these researchers varied remember and forget cue between participants and used a modification of the traditional list-method task. Together, however, the results of the present experiments go beyond this recent work by using the traditional list-method task, using related and unrelated lists as material, and using both simultaneous and successive recall tests. This latter extension is particularly important as it controls for the possibility that a reduced inhibitory function in older adults is "compensated" by an increased susceptibility to output interference to result in normal directed forgetting performance. That output interference may play a role in list-method directed forgetting has recently been demonstrated by Golding and Gottlob (2005). Thus, only if output order is controlled can we unequivocally conclude from equal directed forgetting performance in younger and older adults that older adults show intact inhibition. Exactly this was accomplished in Experiment 2 and Experiment 3 of the present study.

Relation to Previous Item-Method Findings

Using the item-method task of directed forgetting, previous studies reported age-related differences with reduced forgetting in the older adults (Dulaney et al., 2004; Earles & Kersten, 2002; Zacks et al., 1996, Experiment 1; but see Sego et al., in press, Experiment 1). In the present experiments, the list-method task was used to study older adults' directed forgetting and no age-related differences emerged. Prior work in younger adults revealed a number of experimental dissociations between the item-method and list-method task of directed forgetting, indicating that they are mediated by different mechanisms (Basden & Basden, 1998; MacLeod, 1998). Following this line of evidence, the previous item-method and present list-method results suggest that only one of the two directed forgetting mechanisms, that is, the one underlying the item-method task, but not the other, that is, the one underlying the list-method task, is deficient in older adults.

It has been argued that both item-method and list-method directed forgetting reflect the action of an inhibitory mechanism (Zacks et al., 1996). On the item-method task, the inhibitory mechanism is supposed to stop further rehearsal of the TBF items, thus causing differential encoding of TBR and TBF items. On the list-method task, the inhibitory mechanism is supposed to reduce the accessibility of TBF items, thus reducing the items' interference potential in TBR item recall. The two inhibitory mechanisms are thus supposed to operate at different processing stages, the one at encoding and the other at retrieval (see also MacLeod, 1998).

Following this proposal, the present findings suggest that only inhibition at encoding, but not inhibition at retrieval, may be deficient in older adults. This suggestion is consistent with other recent research in which it was demonstrated that older adults show retrieval-induced forgetting (Moulin et al., 2002). Because retrieval-induced forgetting—the detrimental effect of retrieval practice on a subset of learned items on later recall of the unpracticed material—is generally assumed to be caused by retrieval inhibition (Anderson, 2003), the results of Moulin et al. (2002) provide evidence for older adults' intact inhibition at the retrieval stage. This suggestion parallels the present one concerning list-method directed forgetting and indicates that only inhibition at encoding but not inhibition at retrieval may be deficient in older adults.

There has been some debate in recent years about whether directed forgetting is really mediated by inhibition. Regarding the list-method task, for instance, it has been argued that the benefits and costs of directed forgetting result from an internal context change that occurs between the presentation of the two lists in response to the forget cue, rather than from inhibition (Sahakyan & Kelley, 2002; see MacLeod et al., 2003, for another noninhibitory account). Regarding the item-method task, it has been assumed that the forget cue induces participants to discard further rehearsal of the preprocessed items without proposing that the processing is stopped by inhibition (Basden & Basden, 1998; Bjork, 1989; MacLeod, 1998).

Of course, the interpretation of the pattern that older adults show deficient directed forgetting on the item-method task and intact directed forgetting on the list-method task depends on directed forgetting theory. Accordingly, the present results would not challenge the proposal that older adults show a deficit in inhibitory function, if only item-method but not list-method directed forgetting reflected inhibition. On the other hand, if only list-method but not item-method directed forgetting reflected inhibition, then to date, no convincing evidence for an inhibition deficit in older adults' episodic memory would exist at all. By imposing an important restriction on directed forgetting theory, the suggested dissociation between older adults' item-method and list-method directed forgetting may help to unravel the exact nature of the involved mechanisms.

Conclusions

The present study addressed older adults' list-method directed forgetting by studying the recall performance of younger and older adults in a series of three experiments. Across the experiments, the forget cue was varied within and between participants, the two lists were unrelated and related to each other, and recall was simultaneous and successive. We found no evidence for any deficit in older adults' list-method directed forgetting. Because prior work reported evidence for deficient inhibition in older adults' item-method directed forgetting, the picture arises that only the mechanism underlying the item-method task but not the mechanism underlying the list-method task becomes deficient with increasing age. On the basis of the view that the item-method task reflects inhibition at encoding and the list-method task reflects inhibition at retrieval, these results suggest that only inhibition at encoding but not inhibition at retrieval becomes deficient with increasing age.

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