Selective voluntary forgetting in young and young-old adults

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Abstract

Aging is thought to involve a decline in executive-control capacities, although evidence regarding this claim is not always clear. Thus, although studies exist that suggest impoverished inhibitory memory control in older adults relative to younger adults, experiments with the list-method direct forgetting procedure have mostly failed to show adult-age differences in voluntary forgetting. In the present study we aimed to further study this issue by comparing young-old and young adults' performance with the selective directed forgetting (SDF) procedure, which we assumed to involve higher demands of executive control than the standard nonselective procedure. Thus, on the basis of previous studies showing that a critical factor in finding adult-age differences in executive-control tasks is the overall challenge posed by the tasks, we predicted less SDF in older adults than in younger adults. Supporting our hypothesis, across three experiments we show evidence of older adults' impoverished capacity to voluntarily forget episodic memories, although only when the task requires selective forgetting. Ours join other findings to suggest that sensitiveness to detect adult-age differences in cognitive control may strongly depend on the executive-control demands imposed by tasks.

Keywords: selective directed forgetting, executive control, inhibition, episodic memory, cognitive aging

An influential view on cognitive development suggests that aging brings a decline in inhibitory efficiency (Hasher & Zacks, 1988; Hasher, Zacks & May, 1999). Because of this inhibitory deficit, older adults are less able to control for interference from irrelevant (external or internal) stimuli. They also present with less efficient withdrawing from dominant but inappropriate responses. As a result, age-related differences may be observed in processing of task-relevant information. Evidence supporting this inhibitory account of cognitive aging comes from a variety of experimental tasks thought to draw on inhibitory control (for a review see Lustig, Hasher, & Zacks, 2007). Thus, for example, older adults have more difficulty than younger adults on the antisaccade task (Butler, Zacks, & Henderson, 1999; Olincy, Ross, Young, & Freedman, 1997), discarding misleading interpretations of text passages as confronted with conflicting evidence (Hamm & Hasher, 1992), and responding in the Stroop test (West & Alain, 2000), where the aging effect has been found despite controlling for speed of processing.

More relevant for the present work, the age-associated decline in inhibitory control has been also observed in the realm of episodic memory. Radvansky, Zacks, and Hasher (2005), for example, used a memory analog to the negative priming paradigm (e.g., Tipper, 1985) to test the inhibitory-deficit hypothesis. They predicted that if competing memories on trial N are inhibited, the aftereffect of this process should be observable whenever the inhibited memories turn out to be targets on trial $N + 1$. Interestingly, they found that older adults had smaller costs (actually null) than their younger counterparts when recognizing specific pieces of information that had been distracters in previous trials. As Radvansky, Zacks, and Hasher (2005) argued, the fact that the older adults did not show reduced accessibility to negatively primed targets fits well with the idea that aging entails a deficit to inhibit memories that compete for retrieval. More recently, Anderson, Reinholz, Kuhl and Mayr (2011) used the Think/No think paradigm to compare the ability to intentionally inhibit retrieval in younger and older adults. In two experiments they demonstrated that their aged participants, relative to their younger counterparts, showed significantly less forgetting of the items of which retrieval had been suppressed (but see Murray, Muscatell, & Kensinger, 2011). Because forgetting in this paradigm is thought to be the consequence of inhibitory control over retrieval, Anderson, Reinholz, Kuhl, and Mayr's (2011) results also support the hypothesis that aging brings a decline in inhibitory capacities.

List-method Directed Forgetting and Aging

The ability to get rid of no-longer-relevant or outdated memories has also been proposed to involve inhibition (e.g.,Bjork,1989; Bjork, Bjork, & Anderson, 1998; Geiselman, Bjork, & Fishman, 1983; but see MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003 for a different view). When forgetting desired memories is annoying and disturbing, forgetting unwanted memories is thought to be an adaptive process, and some have put forward that an inhibitory-like mechanism accomplishes this control function (e.g., Anderson, 2003; Bjork, 1989; Bjork et al., 1998). Thus, it is not surprising that attempts have been made to test the inhibitory-deficit hypothesis by using an experimental procedure that requires participants to intentionally forget previously learned information. Such a procedure is the list-method directed forgetting[1] (LM-DF). In a standard LM-DF experiment, participants are usually presented with a first list of items to study. Immediately after studying List 1, half of the participants are

[1] 1 A related procedure is the so-called item-method directed forgetting. In this variant subjects view a series of items, each immediately followed by an instruction to remember or to forget the item. After all of the items have been presented, participants' memory is tested. Typically this item-by-item instruction manipulation also leads to memory impairment for items cued to forget. Unlike the list-method directed forgetting, however, the item- method directed forgetting effect is thought to reflect differential encoding for items cued to forget and remember, and it will be no longer considered here.

instructed to forget the whole list (forget group), whereas the remaining half is told to continue remembering List 1 (remember group). After receiving the instruction, all participants are provided with a second study list (List 2) and, finally, they perform a recall test that usually involves both studied lists. Typically, the instruction to forget gives rise to a memory impairment for List 1 in the forget group relative to the remember group (directed forgetting, DF, or cost effect).

Although alternative explanations to the effect have been proposed (e.g., Sahakyan & Kelley, 2002), a well-established account attributes the memory cost observed in LM-DF experiments to a transitory state of inhibition of List 1 items, which is triggered in response to the instruction to forget in order to prevent these items from hindering List 2 later recall (Geiselman et al., 1983; Bjork, 1989, 1998). In support of this account, the forgetting effect vanishes when there is no List 2 to be studied (e.g., Gelfand & Bjork, 1985; Pastötter & Bäuml, 2007) and increases when the number of items of List 2 grows (Pastötter & Bäuml, 2010). Importantly, it has been suggested that this memory cost reflects the operation of an executive-control (inhibitory) mechanism because LM-DF is not found in populations thought to suffer deficit in inhibitory control (e.g., Conway & Fthenaki, 2003; Harnishfeger & Pope, 1996) and in healthy participants when they are to perform a secondary task during List 2 learning (Conway, Harries, Noyes, Racsmány, & Frankish, 2000). Also consistent with the involvement of executive control in LM-DF, Hanslmayr et al. (2012) found that voluntary forgetting is related to specific activity in the dorsolateral prefrontal cortex, a brain region thought to be involved in cognitive control (McDonald, Cohen, Stenger, & Carter, 2000).

From the hypothesis that aging brings a decline in inhibitory control, one would expect older adults to show reduced DF cost, relative to younger adults, in LM-DF experiments. Impoverished capacity to intentionally inhibit episodic memories should make older people recall the to-be-forgotten items to the same extent as the to-be-remembered items. Contrary to this expectation, a number of studies that examined adult-age differences in LM-DF by comparing older adults (typically ranging from 60 to 75 years) and young university students essentially failed to show less forgetting in the first cohort (Sahakyan, Delaney, & Goodmon, 2008; Sego, Golding, & Gottlob, 2006; Zellner & Bäuml, 2006; but see Zacks, Radvansky, & Hasher, 1996). For example, using the standard procedure Sego, et al., 2006; (Experiment 2A) and Zellner and Bäuml (2006) reported comparable forgetting effects in younger and older adults. More recently, Sahakyan et al. (2008; Exp. 1) observed reduced memory impairment in the older relative to the younger participants. However, the authors attributed this age difference to older participants being more reluctant to follow the instruction to forget because they usually believe that they do not need to do anything to forget. This suspicion was confirmed in a second experiment whereby instructions were modified to emphasize the importance of forgetting List 1 and where comparable memory impairments were found in older and younger participants. Hence, Sahakyan et al.'s results join other findings to show no adult-age differences in the LM-DF procedure.[2]

Recently, Aslan and Bäuml (2013) have shown that whereas LM-DF is present in the so-called "young-old" adults (60–75 years), thus replicating previous findings, no DF cost is observed in "old-old" adults (above 75 years). Interestingly, this result agrees

[2] Zacks, Radvansky, and Hasher (1996) reported adult-age differences in directed forgetting with lists of items using an unusual procedure that involved repeated testing of the to-be-remembered items. Participants studied a series of word lists varying in number of items, and after studying each list they were told either to forget or remember the items of each. In the latter case, participants performed an immediate recall test. Finally, participants' memory for the to-be-remembered and to-be-forgotten items was tested. Relative to the younger participants, the older ones showed a lesser recall difference between both types of items that the authors interpreted in terms of a deficit in exerting inhibition over nonrelevant memories. A possible criticism of this study, however, is that the nonstandard testing procedure could have enhanced participants' memory for the to-be-remembered items relative to the to-be-forgotten items. Hence, the lesser memory cost in the older adults could be attributed to enhanced benefits from repetitive testing for the younger participants rather than to older adults' poorer ability to forget

with findings from different cognitive domains suggesting that executive-control processes decline rather late in life (for a meta-analysis see Verhaeghen, 2011). Thus, it would seem that the ability to voluntarily forget irrelevant or unwanted memories (at least as measured with LM-DF procedures) entails control processes that generally operate efficiently in healthy adults under their seventies. Although such a conclusion is suggestive, alternative explanations may be considered. Recent work on the retrieval-induced forgetting (RIF) effect (an incidental type of forgetting that is thought to be an aftereffect of inhibiting competing memories during selective retrieval) suggests that age differences in memory inhibition may result from differences in the control demands imposed by the experimental task. Ortega, Gómez-Ariza, Román, and Bajo (2012) have for example shown that a critical factor in finding adult-age differences in memory control tasks is the overall challenge posed by the tasks. It could then be the case that young-old adults show reduced (if any) memory cost in those LM-DF procedures that tax more executive control than the standard ones used in previous studies. Ortega et al., (2012) reported that the RIF effect was eliminated in older and younger adults under dual-tasking conditions that, thus, were thought to impose high executive-control demands. Interestingly, whereas performing a concurrent three-digit updating task during retrieval did not eliminate the memory impairment in the younger participants (only a five-digit-updating task abolished the effect in the group of university students), the three-digit concurrent updating task was enough to eliminate forgetting in the older group. Thus, Ortega et al.'s findings support the idea that the mechanism underlying RIF taxes inhibitory executive control of memory (see also Román, Soriano, Gómez-Ariza, & Bajo, 2009) and, more important here, suggest that aging brings a progressive loss of this capacity. Also supporting this idea, Aslan and Bäuml (2012) found deficient RIF in old-old adults but not in young-old adults.

Therefore, it could also be the case that a majority of people under 75 years of age may successfully engage in forgetting in the standard LM-DF task because this task only requires moderate levels of memory control and, hence, the task is not sensitive enough to reveal adult-age differences in the ability to intentionally forget.

Selective Directed Forgetting and the Present Work

A variant of the LM-DF procedure that might involve higher demands of executive control than the standard LM-DF procedure is the selective directed forgetting (SDF) paradigm introduced by Delaney, Nghiem, and Waldum (2009; for a related procedure see Kliegl, Pastötter, & Bäuml, 2013). To explore to what extent people can selectively forget only some of the items learned before the cue to forget, Delaney et al. had participants study a List 1 consisting of either thematically related or unrelated sentences about two characters (Alex and Tom) and a List 2 consisting of unrelated sentences about a third character (Joe). After presenting List 1 for study, participants in the forget group were told to forget the sentences concerning Tom and keep remembering the sentences about Alex. In the remember group, however, participants were asked to remember all the sentences about the two characters of List 1. Interestingly, for the forget group, Delaney et al. found that, while no memory impairment was found in the thematic condition (which was expected from the hypothesis that integration protects information from being forgotten, e.g., Gómez-Ariza, & Bajo, 2003; Radvansky, 1998; Smith, Adams, & Schorr, 1978), a SDF effect emerged in the condition with unrelated sentences. In other words, in the forget group, the sentences referring to Tom were significantly less recalled than they were in the remember group, whereas the recall of sentences about Alex were comparable in both instruction groups. Although the precise mechanism underlying SDF remains unknown, it has been suggested that memory inhibition may have a role in producing the effect (Delaney et al. 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013).

The SDF procedure might be especially suitable for exploring individual differences in intentional forgetting if one assumes that the selective nature of the task requires more demanding cognitive control than the standard (nonselective) procedure. The rationale behind this assumption relies upon previous work with the stop-signal task, a well-established procedure to measure inhibitory control over motor responses. Studies using different versions of this task have shown that the age-related differences in inhibition are easier to observe through a selective version of the task (where the stop signal requires suppression of responses to some stimulus but not to others; e.g., Bedard, Nichols, Barbosa, Schachar, Logan, & Tannock, 2002) than when using the nonselective standard version of the stop-signal procedure (Williams, Ponesse, Schachar, Logan, & Tannock, 1999). Hence, one could suggest that the SDF procedure imposes higher demands of memory control because it would require to select and suppress specific memories rather than to proceed to the global forgetting of an entire list. From this view, the process of selecting which information is to be discarded might burden the process in charge of making the target memories less accessible. Thus, relative to the standard DF procedure, the SDF procedure would entail higher level of cognitive control that would surpass the capacity of older adults.

Of course, to what extent the SDF paradigm is a better procedure than the standard one to reveal adult-age differences in intentional forgetting is an empirical question. However, the SDF paradigm has now shown to be useful to investigate differences in memory control between healthy and clinical samples (Gómez- Ariza et al., 2013). Supporting the hypothesis that high anxiety entails impoverished executive control (Bishop, 2009; Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010). Gómez-

Ariza et al. (2013) found reliable SDF in a group of nonclinical adolescents but failed to find the effect in a group of participants diagnosed with social anxiety disorder. Hence, there are reasons to expect older adults to show reduced or null SDF effect relative to younger adults.

The main motivation of the present work was to explore the capacity of older adults to engage in selective voluntary forgetting. If SDF taxes higher executive-control demands than standard directed forgetting and executive-control processes decline with age, one would expect SDF to be absent (or reduced) at an age where standard DF may be usually present. This absence of SDF in older adults may take two forms: First, it is possible that we do not observe forgetting of any of the characters from List1 (i.e., that the to-be-forgotten and to-be-remembered items from List 1 are equally recalled and to a similar extent as in the group cued to remember). If, as stated, the process that makes memories less accessible is hampered by having to select which specific memories are to be suppressed, one would not expect any forgetting to emerge in older adults. On the other hand, it is also possible that the lack of SDF in the older adults may take the form of reduced recall of the entire List1. This might happen because impoverished control capacities may result in difficulties in selecting the appropriate to-be-forgotten information but not in the forgetting process itself. In this case, and as the result of nonselectivity, older adults would end up suppressing all the information in List 1. Although we did not have a clear a priori prediction regarding which of these two outcomes would arise in older adults, the recent results by Gómez-Ariza et al. (2013) with a clinical sample made us expect that deficits in executive control would result in no forgetting at all of List 1 items.

Here we report three experiments in which we tested older adults’ ability to intentionally forget episodic memories. In Experiment 1a we compare young and older adults by using the procedure introduced by Delaney et al., 2009. Experiment 1b basically aimed to overcome some methodological shortcomings of Experiment 1a and was run only with older participants. Experiment 2 was essentially identical to Experiment 1a except for the instructions provided to participants in the forget condition; namely, participants were told to forget all sentences of List 1 rather than a subset of them.

Experiment 1a

Method

Participants. Forty-eight young (*M* = 20.5 years, *SD* = 2.04) and 48 older adults (*M* = 68.31 years, *SD* = 6.66) participated in the experiment. The younger participants were undergraduates from the universities of Granada (Spain, *n* = 22) and Hull (England, *n* = 26) who received course credit. The older participants were recruited through participant pools at the University of Hull (*n* = 32) and a public health center in the province of Granada (*n* = 16). None of the older participants (in this and the next experiments) had a history of neurological disorders or psychiatric conditions. All participants reported being in good health and having normal or corrected vision and hearing. In addition, older participants had at least 11 years of formal education (*M* = 13.23, *SD* = 2.89). To control for global cognitive functioning we administered the short-term memory (STM) (WMS–III) and vocabulary scales from the WAIS (Wechsler, 1997). Older participants showed normal performance (WMS–III with *M* = 16.89, *SD* = 4.07; vocabulary with *M* = 44.87, *SD* = 11.86). The younger participants' mean was 17.23 (*SD* = 3.22) in the WMS–III and 41.67 (*SD* = 6.33) in the vocabulary test. There were no differences between young and older participants in memory span ($p > .50$), but older adults marginally outperformed younger adults in vocabulary ($p > .10$).

Materials and procedure. Participants studied two lists of sentences presented on a 19-inch computer screen. Stimuli were printed in black on white background and appeared in 18-point Courier New font. The first list was basically the thematically unrelated list used by Delaney et al., 2009, although two extra sentences were added. Thus, List 1 consisted of 18 sentences, 9 about Tom and 9 about Alex, presented in alternating order (e.g., "Tom watched TV," "Alex brushed his teeth"). The character to be presented first in the series and the character-action assignation were both counterbalanced across participants. Thus, the predicates associated with Tom for half the participants in each group were associated with Alex in the other half. List 2 consisted of 14 unrelated sentences about Joe (e.g., "Joe played video games," "Joe woke up late"). Each sentence was presented on the screen for 8 s with an interitem interval of 1 s. A Spanish translation of the two lists was used with the Spanish participants.

Upon their arrival, all participants were randomly assigned to one of the two instruction conditions (remember all vs. forget Tom) and informed that they were participating in a memory experiment and that their memory would be tested after studying a set of sentences about different characters. Following List 1 presentation, participants in the groups cued to remember were told the following: "Please, do your best to remember the just-studied sentences." After this, they were asked to solve simple arithmetic operations for 90 s in order to discourage them from rehearsing the material. Finally, participants were told to study List 2. Participants cued to forget were told the following after studying List 1: "At this point you should know that the forthcoming recall task will only test your memory about Alex. Thus, Tom sentences are no longer relevant. To do best on the memory test you should forget all you learned about Tom. Ignoring information about Tom will definitively help you to better recall information about Alex." Special care was taken to highlight the importance of forgetting in the case of the older participants (Sahakyan et al., 2008). Several times during the experimental session, and from the very beginning, participants were told to do their best to strictly follow the instructions provided by the experimenter.

Following List 2 study, all participants again solved a series of math exercises for 90 s and then were provided with a blank sheet of paper and asked to recall and write down as many sentences as possible from List 1. A second blank sheet was handed out to write down sentences from List 2. Four minutes were given to recall each List. The presentation of items and instructions was controlled by E-prime software (Schneider, Eschman, & Zuccolotto, 2002).

After performing the recall task, participants were asked to answer some questions regarding the use of strategies during the study phase and, in the case of the forget-cued group, also asked to report to what extent they took the forget instruction seriously and engaged in memory updating. To do so they were provided with a Likert-like item (ranging from 0 = not seriously at all to 5 = very seriously). At the end of the experimental session, participants performed the vocabulary and the memory span tasks. The session lasted about 40–45 minutes.

Results

In this and the next experiments, recalled items were marked correct if they both contained the studied character-action association and kept the gist of the original sentences. Two independent coders scored the recall performance of each participant. The interrater agreement was greater than 95%. When agreement was not reached, additional coders were considered to solve the differences through discussion. The data from two older participants (one from each instruction condition) were excluded from the analyses because of extremely low performance in the recall test (one of them did not recall any sentence of any of the lists, and the other was the only participant in the remember group who did not recall any sentence of List 2).

We first conducted a mixed factorial analysis of variance (ANOVA) with age (younger and older) and instruction (remember all vs. forget Tom) as between-participants factors and char- acter (Alex, Tom, and Joe) as the within-subject factor on the recall percentages. The younger participants (*M* = 36.34; *SD* = 23.35) significantly recalled more sentences than the older did (*M* = 17.97; *SD* = 18.18), *F*(1, 91) = 48.67, *MSE* = 727, p < .001, η_p^2 = .348 (see Figure 1). No other main effect reached statistical significance. The interaction age x instruction x character was statistically significant[3], F(1, 182) = 7.54, *MSE* = 208, p < .001, η_p^2 = .076, and we followed it up through separate ANOVAS for List 1 and List 2.

List 1 Recall: Selective Directed Forgetting

In order to check for SDF we first performed a 2 (age) X 2 (instruction) X 2 (List 1 character) mixed ANOVA on recall rates. Importantly, the higher order interaction was marginally significant, *F*(1, 90) = 2.86, *MSE* = 182, *p* = .09, η_p^2 = .031, and we carried out a 2 (instruction) X 2 (character) ANOVA in each age group.

The analysis on the younger participants' recall percentages of List 1 items showed a significant effect of the interaction character x instruction, *F*(1, 46) = 6.46, *MSE* = 244,

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[3]Before carrying out specific analyses for our hypothesis, we checked for performance differences as a function of the nationality of participants through a 2 (nationality: English and Spanish) X 2 (age: younger and older) X 2 (instruction: remember and forget) X 3 (character: Tom, Alex, and Joe) mixed analysis of variance (ANOVA) on recall percentages. The analyses showed all sources of variability involving nationality to be nonsignificant except the interaction age x nationality, *F*(1, 87) = 15.84, *MSE* = 602, *p* < .01. Further analyses revealed that the young Spanish participants (*M* = 50%) tended to better recall than their English counterparts (*M* = 33%, *p* < .01), whereas the opposite was true in the older participants (Spanish sample with *M* = 11% and English sample with *M* = 21%, *p* < .05). Importantly, the pattern of the interaction age x instruction x character did not change as a function of nationality (four-way interaction with *F*(1, 174) = 1.83, *MSE* = 206, p = .16).

$p < .05$, $\eta_p^2 = .123$. Further analyses revealed reliable SDF; the group cued to forget recalled fewer items about Tom than the remember-cued group did, $F(1, 46) = 10.49$, $MSE = 453$, $p < .01$, $\eta_p^2 = .186$, whereas no significant difference was found between groups in the recall of items about Alex, $F(1, 46) < 1$, $\eta_p^2 = .008$. The same ANOVA on the older group's recall rates, however, failed to show reliable SDF. The interaction character x instruction was not significant, $F(1, 44) < 1$, $\eta_p^2 = .009$. The forget group recalled as many items about Tom as the remember group did, $F(1, 44) < 1$, $\eta_p^2 = .019$. No significant difference between groups was also found in the recall of items about Alex, $F(1, 44) < 1$, $\eta_p^2 = .003$.

As in previous studies focusing on individual differences in SDF (Gómez-Ariza et al., 2013), we further examined the older adults' performance to determine the extent to which their memory impairment could depend upon the participants' willingness to forget. Specifically, we conducted an additional ANOVA on recall percentages after removing from the analysis five participants in the forget condition who reported not having followed the instruction to forget. The results of this analysis indicated that the lack of SDF did not depend on the participants' willingness to follow the instructions, because the instruction x character the interaction remained nonsignificant, $F(1,39) < 1$, $\eta_p^2 = .009$. The sentences linked to Tom (17.28%) were recalled by the group cued to forget to the same extent as those sentences linked to Alex (19.75%) and as well as the items about Tom in the remember-cued group (19.80%).

Finally, we performed analyses on between-character confusion rates within List 1 (sentences about Tom incorrectly assigned to Alex and vice versa). The mean percentage of source confusions by the younger participants was 2.76 ($SD = 5.62$) in the remember group and 11.67 ($SD = 13.58$) in the forget group. The older participants' means were 18.74 ($SD = 26.80$) and 21.35 ($SD = 30.83$), respectively. A 2 (age) x (instruction) ANOVA showed only the main effect of age to be significant (all other effects were $F < 1$), $F(1, 90) = 8.34$, $MSE = 463$, $p < .01$, $\eta_p^2 = .08$. On average, the older adults ($M = 20.04$, $SD = 28.60$) made more source confusions than the younger participants ($M = 7.22$, $SD = 11.23$).

Output Order Analysis

To assess whether output interference could account for the memory impairment of Tom sentences in the younger participants, we calculated output position percentiles for each participant according to the procedure introduced by Bjork and Whitten (1974). The rationale behind this analysis is that if participants in the forget group tended to recall Alex sentences before Tom sentences, this could have led to lower the recall of the Tom items because of output interference.

A 2 (character) X 2 (instruction) mixed ANOVA on younger participants' output position scores revealed that neither source of variance reached significance (all *p*s < .21). There were no differences in output order between the sentences associated to Tom ($M = .55$; $SD = .16$) and the sentences associated to Alex ($M = .60$; $SD = .17$) in the remember group ($F < 1$) nor were there differences between the output order for Tom and Alex sentences in the forget group ($M = .63$; $SD = .16$ and $M = .56$; $SD = .17$, respectively), $F(1, 35) = 1.04$, $MSE = .05$, $p = .31$, $\eta_p^2 = .029$. This pattern suggests that output interference did not play a relevant role in producing SDF in the younger participants.

List 2 Recall

Although our hypothesis focused on List 1, for completeness we also performed analyses on List 2 recall. A 2 (age) X 2 (instruction) ANOVA on recall percentages showed the interaction to be significant, $F(1, 75) = 7.50$, $MSE = 352$, $p < .01$, $\eta_p^2 = .091$, and we followed it up by carrying out analyses for younger and older participants separately. The younger participants cued to forget recalled more sentences about the List 2 character that those cued to remember, $F(1, 75) = 6.28$, $MSE = 352$, $p < .05$, $\eta_p^2 = .077$. The same analysis on the older participants' recall rates, however, did not show significant effect of instruction on List 2 recall, $F(1, 75) = 1.77$, $MSE = 352$, $p = .19$, $\eta_p^2 = .023$.

Intrusions From List 1

Finally, we analyzed intrusions from List 1 during List 2 recall (attributing to Joe actions that were previously learned either related to Tom or to Alex) because they could be informative about List 1 items' accessibility. A 2 (young vs. old) X 2 (remember vs. forget) ANOVA on overall intrusion percentages showed that older participants ($M = 22.7$, $SD = 30.6$) made more intrusions than younger participants ($M = 8.7$, $SD = 19.3$) when recalling List 2 items, $F(1, 87) = 7.61$, $MSE = 620$, p < .01, $\eta_p^2 = .080$. Importantly, this age effect was qualified by an interaction with instruction, $F(1, 87) = 5.77$, $MSE = 620$, p < .05, $\eta_p^2 = .062$. Although there was no difference in intrusion percentages between younger and older adults in the remember condition (younger: $M = 15.2$; $SD = 25$; older: $M = 17$, $SD = 24.2$, $F < 1$), the difference was statistically significant in the forget condition (younger: $M = 2$, $SD = 5.9$; older: $M = 29$, $SD = 40$, respectively, $F(1, 87) = 12.88$, $MSE = 620$, $p < .01$, $\eta_p^2 = .129$). The frequency of intrusions related to Alex and Tom, however, was statistically similar in younger (Alex: $M = 58\%$; Tom: $M = 42\%$) and older participants (Alex: $M = 52\%$; Tom: $M = 48\%$) and did not depend on the instruction (all ps > .60).

Discussion

The present results reveal that in a modification of the LM-DF procedure introduced by Delaney et al., (2009) younger and older participants showed a different pattern of memory performance as a function of instruction. Whereas the former showed selective memory impairment for the to-be-forgotten items of List 1, which replicates previous findings (Delaney et al., (2009); Gómez-Ariza et al., 2013; Kliegl et al., 2013; but see Storm, Koppel, & Wilson, 2013), no effect of the forget instruction was evident in the older participants, who recalled as many to-be-forgotten items as to-be- remembered items.

The absence of intentional forgetting in our older participants is important because previous studies have shown comparable DF effects in older adults (less than 75 years) and younger participants (Aslan & Bäuml, 2013; Sahakyan et al., 2008; Sego et al., 2006; Zellner & Bäuml, 2006; but see Zacks et al., 1996). However, because we used a modification of the DF procedure that requires participants to forget selectively, the demands for cognitive control may have also been increased. That is, the introduction of this selectivity component in the procedure might make older adults less capable of forgetting after being cued to do so. Thus, our findings could indicate that the SDF procedure is more demanding of memory control and, hence, more sensitive than the standard DF procedure to individual differences in the ability to intentionally forget.

However, before drawing strong conclusions from our findings in Experiment 1a, we wanted to rule out the possibility that our results were because of the general low performance of the older participants in the memory task, which could have prevented forgetting from being easily observed. Because the task was difficult and the older participants showed low recall level, it might be argued that the absence of SDF in our older participants reflected a floor effect. Thus, we decided to run a new SDF experiment with older adults using the same procedure as in Experiment 1a, but reducing the memory load of the task. The goal was to improve the overall memory performance of the older participants and to be able to discard potential floor effects.

Experiment 1b

Method

Participants. Forty-four older adults (*M* = 65.32 years, *SD* = 4.78) participated in this experiment. They were recruited through participant pools at the University of the Balearic Islands (*n* = 10) and the University of Granada (*n* = 34). All participants reported having normal or corrected vision/hearing as well as having at least 11 years of formal education (*M* = 13.44, *SD* = 2.14). As in Experiment 1a, participants showed a good performance on the STM subscale from the WMS–III (*M* = 14.95, *SD* = 2.98) and the vocabulary subscale (*M* = 47.53, *SD* = 6.43) from the WAIS test.

Materials and procedure. These were the same as those used in the Experiment 1a except for the number of sentences conforming List 1 and List 2. From the results of the previous experiment we selected the 12 List 1 sentences with the highest recall rates to be used in the present experiment. In addition, we randomly removed two sentences of the List 2 from Experiment 1a. Thus, participants now studied a first list composed of 12 (instead of 18) sentences (6 about Tom and 6 about Alex) and then a new list with 12 sentences about a third character.

Results

List 1 Recall

To check for SDF we performed an ANOVA with instructions (remember all vs. forget Tom) x List 1 character (Tom vs. Alex) that failed to yield significant effects [main effects with F < 1 and interaction with *F*(1, 42) = 1.26, *MSE* = 160, *p* = .27, η_p^2 = .029].

The forget group recalled Tom items to the same extent as the remember group did, *F*(1, 42) < 1, η_p^2 = .010. The difference between both groups regarding Alex items was also not statistically significant, *F*(1, 42) < 1, η_p^2 = .004. In addition, this pattern remained the same after removing from analyses the data from 5 participants who reported not following the instruction to forget. Hence, no evidence of forgetting was found in the present experiment despite observing an overall enhancement in List 1 recall relative to Experiment 1a [*M*Exp1 = 17.87, *SD*Exp1 = 16.12; *M*Exp2 = 26.62, *SD*Exp2 = 16.12; *F*(1, 86) = 3.94, *MSE* = 519, p < .05, η_p^2 = .044. (See Figure 1).

We also looked at between-character confusions within List 1. The percentage of confusions was numerically lower in the remember group (M = 9.47, *SD* = 18.38) than in the forget group (M = 18.93, *SD* = 32.00), although the difference did not reach statistical significance, F(1, 42) = 2.48, *MSE* = 398, p = .12, η_p^2 = .056. The mean percentage of source confusions in Experiment 1b (M = 12.92, *SD* = 24.78) was marginally lower than that in Experiment 1a (M = 22.73, *SD* = 30.64), F(1, 84) = 2.89, *MSE* = 772, p = .09, η_p^2 = .033.

List 2 Recall and Intrusions From List 1

Analysis on List 2 revealed that the instruction did not have any effect on correct recall, *F* < 1 (see Figure 1). Likewise, the percentages of intrusions from List 1 did not vary as a function of the instruction provided before studying List 2 (remember group: *M* = 10.15, *SD* = 20.77; forget group: *M* = 15.68, *SD* = 28.46, *F* < 1) nor the List 1 character (intrusions from Tom: *M* = 12.5, *SD* = 32.57; intrusions from Alex: *M* = 14.77, *SD* = 35.07, *F* < 1). The interaction also failed to reach statistical significance (*F* < 1). Finally, the distribution of intrusions from Alex and Tom were statistically similar in both instruction groups (Alex: *M* = 53%; Tom: *M* = 47% *p* > .70).

Analysis of Combined Data of Older Participants From Experiments 1a and 1b

In a further attempt to find any evidence of SDF in our older participants we combined data from Experiments 1a and 1b. First, we included all participants in the analyses. The mixed ANOVA with instruction and List 1 character as factors showed no statistically significant effects [main effects with $F < 1$ and interaction with $F(1, 88) = 1.64$, MSE = 135, p = .20, η_p^2 = .018]. Next, we removed from the analyses those individuals who showed low memory performance. Specifically, we used the correct recall of sentences related to Alex as the criterion variable to take cases into or out of analyses because these items were always to be remembered (regardless of instruction). Thus, we selected only participants with recall of Alex above 33rd percentile. Twenty participants cued to remember and 20 participants cued to forget were included in the analyses[4]. The corresponding instruction x List 1 character mixed ANOVA showed no effect of instruction, $F < 1$, nor the interaction, $F(1, 38) = 1.34$, MSE = 139, p = .25, η_p^2 = .031. (See Figure 2). The recall of items related to Tom was comparable in the two instruction groups, $F(1, 38) < 1$, η_p^2 = .01, and similar to the level of recall of Alex, $F(1, 38) < 1$, η_p^2 = .004. The only statistically significant effect was character, $F(1, 38) = 8.08$, MSE = 139, p = .01, η_p^2 = .175. Overall, the sentences related to Tom (M = 28.47, SD = 20.87) were more poorly recalled than those related to Alex (M = 35.97, SD = 16.38).

Discussion

Results from Experiment 1b basically replicate those from Experiment 1a showing no selective forgetting in older adults. Even when only six different facts were studied about the two List 1 characters, participants over 60 years old failed to selectively

[4] A power analysis using G□Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that a total sample of 38 people was large enough to detect a2□ 2 mixed interaction with □p 2 □ .09 (25% less than the effect size found for the younger participants in the Experiment 1a with 80% power and alpha at 5%).

forget. Importantly, the overall memory enhancement observed in the present experiment (more correct responses and fewer character misattributions) relative to Experiment 1a, makes it difficult to attribute the lack of experimental effect to floor performance. In support of this conclusion, SDF was absent even when the data of Experiments 1a and 1b were combined and participants with the lowest performance were removed.

The finding that older adults do not show SDF when previous studies have shown similar DF effects for older and younger adults is suggestive of how different SDF and DF may be. One reason to expect age differences in the SDF procedure is that memory selection could impose high demands of cognitive control that would surpass the capacity of older adults. If so, then removing the selectivity component of the SDF procedure would turn the task into a standard DF procedure and comparable forgetting should be observed in younger and older adults. Thus, we conducted a new experiment with essentially the same material and procedure as Experiment 1a except for the nature of the instruction to forget; namely, in Experiment 2 the cue required participants to forget all the sentences in List 1 rather than only a subset of them. Hence, we predicted that to the extent that the failure to find any evidence of forgetting for older adults in Experiments 1a and 1b was because of the selective component of the task, in Experiment 2 we should find comparable forgetting in younger and older adults, thus replicating previous DF research.

Experiment 2

Method

Participants. Forty-eight young (M = 19.75 years, *SD* = 2.16) and 44 older adults (M = 64.2 years, *SD* = 3.19) participated in the present experiment. The younger participants were undergraduates from the Universities of Granada and Jaén who received course credit for participating. Most of the older participants were recruited from a pool of participants at the Universities of Granada and Jaén. All of them reported over 10 years of formal education. As in Experiment 1, STM and vocabulary tests from the WAIS were administered and the older participants showed normal performance on them (M = 14.9, *SD* = 3.2 and M = 44.3, *SD* = 16.2, respectively). The younger participants had mean scores of 15.6 (*SD* = 2.7) and 42.53 (*SD* = 5.14) on the WMS–III and vocabulary tests, respectively. There were no differences between older and younger adult participants in STM ($p > .50$) or vocabulary ($p > .21$).

Materials and procedure. The materials and procedure of Experiment 2 essentially matched those in Experiment 1a with the exception that the participants assigned to the forget condition were told to forget the whole set of List 1 sentences rather than just a subset of them. Specifically, they were told: “At this point you must know that the forthcoming recall task will not test your memory about the just-learned items. List 1 was given just as an example and the presented sentences are no longer relevant. Instead, you will be tested on the next list that I will present you now. Therefore, to do your best in the forthcoming memory test on the material that you are still to learn, you should forget all you have learned so far. Ignoring information about the previous list will definitively help you to better recall relevant information.” Each of the 18 sentences included in List 1 started with the name of just one character (Tom). As in the previous experiment, test participants were first required to recall List 1 and then List 2.

Results and Discussion

We followed the same criteria of Experiments 1a and 1b to mark recalled items as correct. Figure 3 shows the correct recall for each group as a function of list and instruction. The data of two older participants in the remember condition were removed from the analyses because of an extremely low general performance in the memory tasks.

First we performed a 2 (age: younger and older) x 2 (instruction: remember and forget) x 2 [character (List): Tom and Joe] mixed ANOVA on correct recall percentages. All main effects reached statistical significance: young adults (*M* = 42.27; *SD* = 20.52) recalled more sentences than older adults (*M* = 24.28; *SD* = 15.73), $F(1, 86) = 43.03$, *MSE* = 421, $p < .01$, $\eta_p^2 = .333$; more items were recalled in the remember condition (M = 38.64; *SD* = 20.58) than in the forget condition (*M* = 31.4; *SD* = 20.66), $F(1, 86) = 4.80$, *MSE* = 421, $p < .05$, $\eta_p^2 = .052$; and List 2 (*M* = 37.53; *SD* = 19.64) was better recalled than List 1 (*M* = 32.34; *SD* = 21.85), $F(1, 86) = 7.26$, *MSE* = 177, $p < .01$, $\eta_p^2 = .078$. Age did not interact with any factor (both first-order interactions with $p > .25$ and second-order interaction with $F < 1$).

List 1 recall: Directed Forgetting

A 2 (age) x 2 (instruction) between-participants ANOVA on List 1 recall confirmed a main effect of instruction, $F(1, 86) = 17.97$, *MSE* = 283, $p = .01$, $\eta_p^2 = .315$ and a nonsignificant effect of the interaction, $F(1, 86) = 1.36$, *MSE* = 283, $p = .25$, $\eta_p^2 = .016$. The cost of the instruction to forget was observed in the group of younger participants, $F(1, 86) = 15.66$, *MSE* = 283, $p < .01$, $\eta_p^2 = .154$, as well as in that of older participants, $F(1, 86) = 4.42$, *MSE* = 283, $p < .04$, $\eta_p^2 = .049$.

List 2 Recall

The 2 (age) x 2 (instruction) ANOVA showed age to be the only significant effect, $F(1, 86) = 22.74$, *MSE* = 314, $p < .01$, $\eta_p^2 = .172$ (other effects with $F < 1$). Although the reason why the cue to forget did not lead to recall enhancement for List 2 in this experiment is not evident, it is now known that having participants recall List 2 after recalling List 1 (such as is done in our experiments) quite often reduces recall enhancement for List 2 (see Pastötter, Kliegl & Bäuml, 2012). The group of older participants (M = 28.06; *SD* = 20.30) recalled fewer items than their younger counterparts (M = 45.83; *SD* = 13.87).

Intrusions from List 1

As in the previous experiments, intrusions from List 1 during List 2 recall were computed and analyzed through a 2 (age) x 2 (instruction) ANOVA. The analysis only showed a main effect of age (other effects were F < 1), F(1, 86) = 11.93, *MSE* = 345, p < .01, η_p^2 = .122. The older participants (M = 26.5%, *SD* = 21.17) made more intrusions than the younger ones (M = 13%, *SD* = 15.54).

General Discussion

Previous studies with LM-DF procedures in older adults under 75 years of age have mostly failed to show reduced forgetting effects relative to younger adults (Aslan & Bäuml, 2013; Sahakyan et al., 2008; Sego et al., 2006; Zellner & Bäuml, 2006; but see Zacks et al., 1996). In the present work we aimed to further study this issue by comparing young-old and young adults' performance with the selective directed forgetting procedure (Delaney, Nghiem, & Waldum, 2009; Gómez-Ariza et al., 2013). Because in this task the instruction is to forget only a subset of List 1 items, we assumed that successfully achieving this goal would involve higher demands of memory control than following an instruction to forget in a nonselective way, such as is required in standard LM-DF procedures. Selecting and suppressing some memories could be more demanding than suppressing without need of selection. If so, and on the basis of previous research suggesting that aging entails a deficit in executive control (e.g., Andrés & Van der Linden, 2000; Braver & West, 2008; Gunning-Dixon, & Raz, 2003; Ortega et al., 2012; West, 1996), we predicted older people not to show selective directed forgetting. Supporting this hypothesis, in three experiments we show evidence of older adults' impoverished capacity to voluntarily forget episodic memories, though only when the task required selective forgetting.

Using the procedure introduced by Delaney et al., (2009), in Experiment 1a we observed SDF only in young adults. The younger participants who were cued to forget the information associated to one of the List 1 two characters showed selective memory impairment for the to-be-forgotten items relative to the participants who were instructed to keep remembering the two characters. Finding the SDF effect in young people is important: whereas it has been replicated elsewhere (Gómez-Ariza et al., 2013; Kliegl et al., 2013), failures to observe this phenomenon have also been reported (Storm et al., 2013).

Of relevance here, the pattern of results for the older participants was completely different from that for the younger ones because no differences in recall were observed between the groups cued to forget and remember. Thus, the older group failed to show any memory cost following the instruction to selectively forget. The absence of SDF in older participants does not seem to be due to their overall lower performance. Although it could be argued that this low memory performance (below 20%) could have made it difficult to detect an effect of the forget cue in Experiment 1a, we run a new experiment (Experiment 1b) with essentially the same task except for the smaller number of items per list presented to the participants. Replicating those from Experiment 1a, results from Experiment 1b showed no evidence of forgetting in a new sample of participants over 60 years of age. In fact, we failed to observe forgetting even when combining data from the two experiments and considering in the analyses only participants with the highest level of performance.

Interestingly, the lack of directed forgetting found in older adults in Experiments 1a[5] and 1b contrasts with the reliable effect found in Experiment 2 where DF effects were present in both older and younger participants and not significantly different in the two groups. In Experiment 2 we slightly modified the procedure of Experiment 1a so that participants were asked to forget the complete set of sentences comprising List 1 rather than asking them to only forget a subset of them. In this way, Experiment 2 essentially involved a standard LM-DF procedure, whereas Experiment 1a (like Experiment 1b) conformed to a selective LM-DF procedure. Hence, it seems that selective voluntary forgetting imposes high demands of memory control that surpass the capacity of older people. Specifically, we suggest that it is the concurrent operation of memory selection and downregulation that is affected with aging. On the basis of the data showing that the lack of SDF took the form of no forgetting at all, one could even argue that selectivity cannot be the only process playing a role in older adults' failure to selectively forget. Otherwise they would have shown general forgetting of List 1 items. Thus, with aging the process of making memories less accessible (i.e., inhibition) would be more easily hampered by having to select which specific memories are to be forgotten than having to forget the whole list. If so, and also from the proposal that the ability to update episodic memory depends on executive-control processes (Anderson, 2005; Con- way,

[5] A potential criticism of Experiment 1a is that the sample of older participants was slightly older than the same sample in the Experiment 2 (68.31 and 64.2, respectively; $p < .05$), which could have made it difficult to observe SDF in the older adults. To deal with this possibility, we split this sample into two age subgroups (n = 24 $\leq$ 67 y-o and n = 22 $\geq$ 68 y-o) and checked for SDF effects by performing nonparametric analyses. In both subgroups the results were exactly the same; namely, the participants cued either to forget or remember recalled the same amount of items about Tom and Alex (all with *p*s > .31). Hence, even the younger-old participants in the Experiment 1a failed to show any evidence of memory cost following the instruction to forget.

et al., 2000; Delaney & Sahakyan, 2007; Hanslmayr et al., 2012), our results agree with other data reporting adult-age differences in executive control of episodic memory (e.g., Anderson, et al., 2011; Aslan & Bäuml, 2013; Ortega et al., 2012; May & Hasher, 1998; Radvansky et al., 1996). Aging brings a decline in executive-control capacities (e.g., Andrés & Van der Linden, 2000; Braver & West, 2008; Gunning-Dixon & Raz, 2003; Lustig et al., 2007), and exerting control over outdated memories to make them less accessible (in favor of more relevant ones) becomes more vulnerable with age.

In support of an impoverished ability to downregulate episodic memory with aging, across experiments we found older adults to be more prone to proactive interference than younger adults be- cause they made more intrusions from List 1 when recalling List 2 items (for related results see Hasher, Chung, May, & Foong, 2002). Of special relevance, intrusion errors in the SDF procedure were especially sensitive to instructions provided after List 1 study. Although no age differences exist regarding the remember groups, those older participants cued to forget made more List 1 intrusions than their younger counterparts as recalling List 2 items. Hence, younger (but not older) adults seem to have been successful in forgetting irrelevant memories when cued to do so.

At first sight, our finding would seem in conflict with that of Aslan and Bäuml (2013) showing that voluntary forgetting is a “late-declining” capability only absent in old-old adults. However, this apparent discrepancy can be easily explained by considering that a) “executive control” is not an all-or-nothing capacity and b) age differences in the ability to intentionally forget may result both from variations in this capacity and also from differences in the executive-control demands imposed by the task (Ortega et al., 2012). Thus, because in Experiments 1a and 1b we used a (selective) directed forgetting task that putatively imposed more control demands than the standard (nonselective) one used in previous studies (Aslan & Bäuml, 2013; Sahakyan et al., 2008; Sego et al., 2006; Zellner & Bäuml, 2006), our task might be more sensitive to age differences in memory executive control. Hence, although only older adults over 75 years old would show a breakdown in nonselective voluntary forgetting, the deficit in selective intentional forgetting would become apparent much earlier.

The fact that older adults do not show SDF seems to fit with an inhibitory-deficit framework (Hasher & Zacks, 1988). If SDF is thought as an aftereffect of an inhibitory process recruited to cause loss of accessibility of outdated memory traces (e.g., Delaney et al., 2009; Gómez-Ariza et al., 2013), then our findings suggest that older (but not younger) adults would fail to downregulate accessibility of specific episodic memories after receiving the selective forget cue. Future research should shed light onto how this down- regulation is implemented in selective voluntary forgetting as well as how it changes with aging. For the case of nonselective directed forgetting, Hanslmayr et al. (2012) have suggested a causal role of DLPFC in driving forgetting by decreasing neural synchrony. Specifically, Hanslmayr et al. put forward that reduced phase synchronization might be related to the inhibition of the original encoding context of the to-be forgotten items, which would make these items harder to recall in a later test. However, it is not evident to us how context-based explanations (inhibitory or not) may account for SDF effects (see below).

Whereas an inhibitory account of SDF emphasizes the role of executive control in retrieval, memory control could also be exerted at encoding and SDF could arise from exerting selective rehearsal on the to-be-remembered items of List 1. If so, the different pattern of performance in young and older adults in the SDF procedure could be related to differential ability to encode information rather than differences in inhibiting nonrelevant memories (e.g., after they were cued to forget, younger participants could have managed to rehearse Alex items more times than older adults). Two aspects of our study, however, preclude interpretation of SDF in terms of selective rehearsal. First, in order to minimize List 1 rehearsal, participants were asked to perform a distracter task right after receiving the forget/remember cue. More importantly, the selective rehearsal hypothesis would lead to expect the forget-cued younger group to show lower recall of Tom items (because less encoding resources were devoted to them) but enhanced recall of Alex items (because full attention was paid to this character) relative to the remember group. Contrary to this, we found that both instruction groups recalled the to-be-remembered items of List 1 to the same extent (for similar results see Delaney et al., 2009; Gómez-Ariza et al., 2013, and Kliegl et al., 2013). This finding suggests that selective rehearsal does not underlie SDF in younger adults and that it is not related to the lack of memory cost in older adults. Nevertheless, further research is clearly needed before drawing strong conclusions regarding the role of rehearsal in SDF.

The fact that younger (but no older) adults show SDF seems difficult to accommodate to a general context-change account of LM-DF forgetting. According to the context-change account of LM-DF (e.g., Sahakyan & Kelley, 2002), directed forgetting reflects a mismatch between the study and the test contexts for List 1 in response to the forget instruction. In the memory test, the retrieval context matches the encoding context for List 2 better than that of List 1, producing reduced recall of List 1 items. Consistent with this hypothesis, Sahakyan and Kelley (2002; see also Sahakyan & Delaney, 2003 and Delaney & Sahakyan, 2007) conducted two experiments in which an internal context change was deliberately induced between the study of List 1 and List 2 in the absence of an instruction to forget. Their results mimicked the typical pattern of List 1 forgetting and, thus, provide support for a context-based hypothesis of DF. Importantly, the SDF effect does not fit well with a general context-change account of forgetting that follows the instruction to forget as sentences about the two List 1 characters were learned in the same context before receiving the cue to forget one of them. Hence, a general context-change theory of directed forgetting would predict that this cue would limit the accessibility of the whole set of List 1 rather than selectively impair a subset of it. In addition, the absence of SDF effect in the older group cannot be easily attributable to diminished vulnerability to context changes in older adults. In agreement with the idea that context-change does not underlie SDF, previous research has shown older adults to be as prone as younger adults to forgetting after inducing mental context changes (Sahakyan et al., 2008). Hence, if context change played a role in SDF memory cost should also have been evident in our older participants in Experiments 1a and 1b.

Finally, a potential account of our main finding deserves commentary. Because aging has also been shown to bring an associative memory deficit (e.g., Naveh-Benjamin, Kilb, & Reedy, 2004), one could argue that it is this memory shortage, rather than a deficit in executive control, that underlies older adults' failure to show SDF. Put simply, the inability to forget in the SDF procedure could be a consequence of a failure to differentiate which actions belonged to each of the List 1 characters. After all, without accurate memories on the facts associated to each character, any of us would find puzzling the task of suppressing some of these memories. In opposition to this argument, we think that the rates of character-list confusions among older participants are not high enough (particularly in Experiment 1b with less than 10% in the remember group), to easily attribute the absence of SDF to a deficit in associative memory. More importantly, should an associative memory deficit play a role in preventing SDF from emerging in older adults who are able to forget in a selective way, one would expect SDF to show up when source confusions within List 1 are marked as correct responses. Under this scenario, those facts originally associated with the to-be-remembered character but incorrectly linked to the character to be forgotten during the recall test should be better recalled than the facts originally associated to the to-be-forgotten character that were successfully forgotten. To assess this possibility, we reanalyzed the older adults' data from Experiments 1a and 1b after including between-character confusions within List 1 as correct responses. Neither source of variability reached statistical significance when the data from the two experiments were analyzed separately and jointly (all Fs < 1), which parallels the results obtained when source confusions are marked as incorrect. Altogether, this suggests that the failure to find SDF in our experiments does not seem to relate to a deficit in retrieving detailed information.

Conclusion

To conclude, across three experiments we showed adult-age differences in directed forgetting but only when participants were cued to selectively forget. We argue that engaging in selective intentional forgetting entails higher demands of executive control to downregulate irrelevant memories, which is what makes older adults less able to successfully accomplish this task. While in agreement with previous results showing reduced memory control capacities with aging, ours also join other findings to suggest that sensitiveness to detect adult-age differences in cognitive control may strongly depend on the control demands imposed by tasks.

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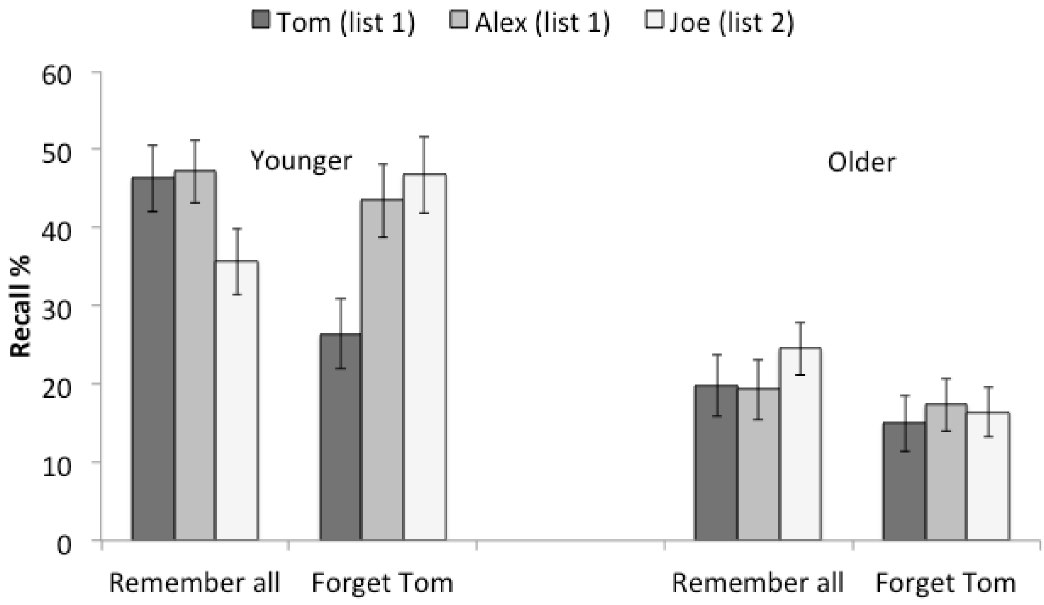
FIGURE 1



Tom (list 1)
Alex (list 1)
Joe (list 2)
60
50
40
30
20
10
0
Recall %
Younger
Older
Remember all
Forget Tom
Remember all
Forget Tom

FIGURE 2

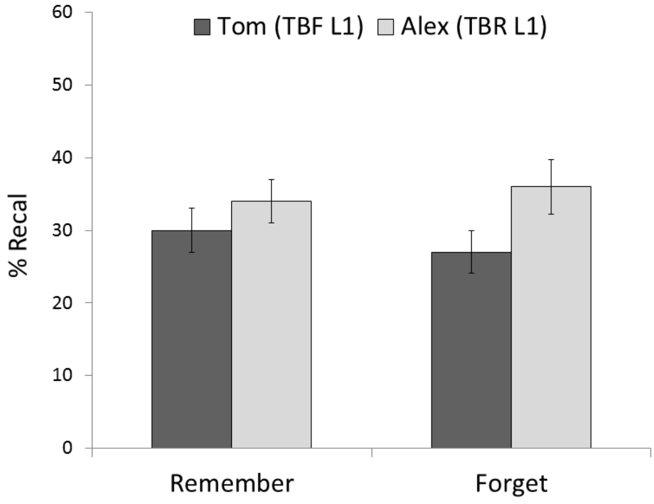
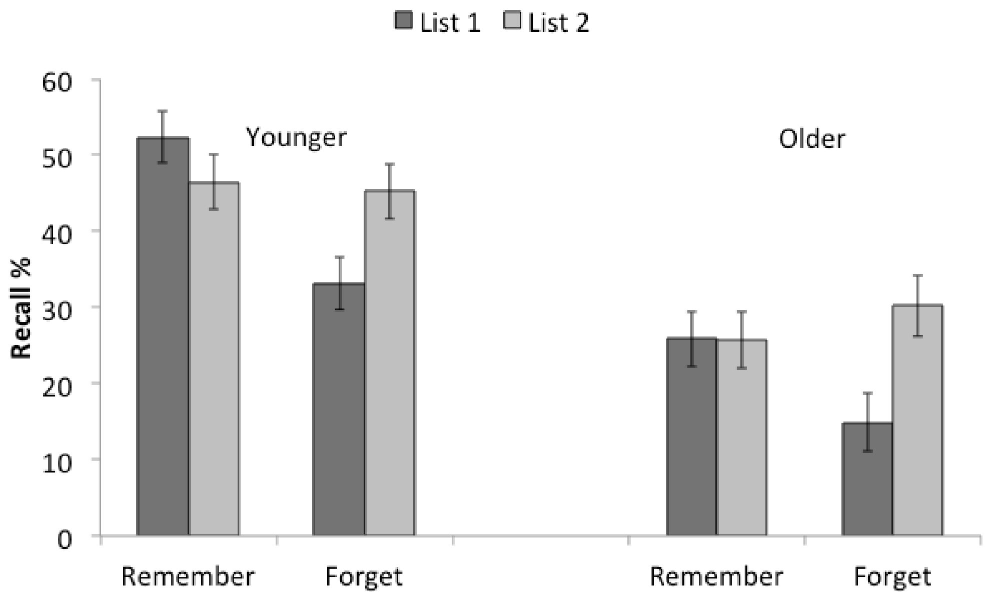


FIGURE 3



List 1
List 2
60
50
40
30
20
10
0
Recall %
Younger
Older
Remember
Forget
Remember
Forget

FIGURE CAPTIONS

Figure 1. Mean percentages of correct recall as a function of age, instruction and list in Experiment 1. Error bars represent standar error of mean.

Figure 2. Combined mean percentages of correct recall of the older adults from Experiments 5 and 6, after removing participants with the lowest memory performance. Error bars represent standard errors of mean.

Figure 3. Mean percentages of correct recall as a function of age, instruction and list in Experiment 2. Error bars represent standar error of mean.