Canadian Journal of Experimental Psychology /
Revue canadienne de psychologie expérimentale

ISSN: 1196-1961

2022, Vol. 76, No. 3, 210–217
https://doi.org/10.1037/cep0000292

Aging and Directed Forgetting: Evidence for an Associative Deficit but No Evidence for an Inhibition Deficit

Pelin Tanberg, Myra A. Fernandes, and Colin M. MacLeod
Department of Psychology, University of Waterloo

Intentional forgetting aims to prevent unwanted information from being stored in long-term memory. Surprisingly, past research has shown that, relative to younger adults, older adults recall and recognize more to-be-forgotten information. It has been suggested that this occurs because older adults have a deficient ability to inhibit information. In two experiments, we examined memory differences between older and younger adults in an item-method directed forgetting task. Participants viewed words one at a time during a study phase, each followed by a cue to remember (R) or to forget (F). In Experiment 1, participants' later recognition of both types of items was assessed, followed by a separate source discrimination test for the cue that had been associated with each word at study. In Experiment 2, memory was assessed using a three-response recognition test, indicating whether each word was either new or previously studied and, if previously studied, whether it was associated with an R cue or an F cue. In both experiments, older and younger adults recognized more to-be-remembered items than to-be-forgotten items, the typical directed forgetting effect (DFE). Contrary to past reports, older adults did not remember more to-be-forgotten items than did younger adults, inconsistent with an inhibitory deficit. Older adults were, however, less accurate than younger adults in identifying cue associations for both R and F items, consistent instead with an associative memory deficit.

Public Significance Statement

Intentional forgetting allows us to update the contents of our memory with the most current information. Previous research suggested that older adults are not as efficient as younger adults in filtering out stored information that is no longer relevant (e.g., an expired phone number). Here, we demonstrate that, in fact, older adults can intentionally forget information just as well as younger adults. Older adults, however, were less able to form the associations between necessary for identifying which information should be remembered and which should be forgotten.

Keywords: intentional forgetting, item-method-directed forgetting, aging, inhibition

Ordinarily, we intend to remember most information because forgetting tends to have negative consequences and can lead to embarrassment. When performed intentionally, however, forgetting can be a beneficial process, helping to ensure that memory stays up-to-date and uncluttered. As just one salient illustration, to efficiently retrieve an updated email account password, we must purge the old account password from memory, otherwise the outdated information would be likely to interfere.

For over a half century, researchers have studied intentional forgetting in the laboratory using a paradigm called directed forgetting. In the item-method Version,[1] participants study individual items for a later memory test, with each item cued after its presentation as either to-be-remembered (R) or to-be-forgotten (F). Participants are instructed that their memory will be assessed for the R items but not for the F items. During a later retrieval test, however, participants are in fact tested on all items. Decades of research (see MacLeod, 1998, for a review) have confirmed better memory for R-cued items than for F-cued items, a performance difference called the *directed forgetting effect (DFE)*.

Two principal accounts have been proposed to explain this effect. According to the *selective rehearsal* account (e.g., Bjork, 1972; MacLeod, 1975), each item is maintained in working memory until its cue is presented. Upon presentation of an R cue, participants elaboratively rehearse the item to further commit it to long-term

Pelin Tanberg https://orcid.org/0000-0001-5073-4844

This article is published to honour the career of William E. Hockley. The authors thank Bill, a devoted supervisor, colleague, and friend, for his dedication to research and for his continuing support and encouragement. This research was supported by an Alexander Graham Bell Canada Graduate Scholarship (Pelin Tanberg) and by Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grants A7459 (Colin M. MacLeod) and 2020-03917 (Myra A. Fernandes). Data from this study are available at https://osf.io/nv4yk/.

Correspondence concerning this article should be addressed to Pelin Tanberg, Department of Psychology, University of Waterloo, 200 University Avenue West, Waterloo, ON N2L 3G1, Canada. Email: pelin.tan@uwaterloo.ca

[1] There are two main directed forgetting paradigms in the literature. In the other one, called the list method, participants study a first list of items that they are then instructed to forget and a second list that they are instructed to remember. This difference in procedure corresponds to blocked versus randomized instructions.

memory. Upon presentation of an F cue, however, participants terminate rehearsal of the item, thereby dropping it from working memory. This single process—differential rehearsal of the R and F items—ensures that R items are more available than F items for the subsequent memory test (Tan et al., 2020).

In contrast, under the *attentional inhibition* account (e.g., Fawcett & Taylor, 2008) dropping an F item from working memory is assumed to require an active mechanism. Upon presentation of an F cue, participants withdraw attention from that item, a form of inhibition that reduces the likelihood of long-term retention of F items. This inhibitory mechanism is taken to be cognitively demanding such that, only once it is completed, can elaborative encoding of previous R items be undertaken. This is therefore, a two-process account—inhibition of F items and elaborative rehearsal of R items.

The attentional inhibition account first gained momentum from the findings of Zacks et al. (1996), who compared the performance of older and younger adults in item-method-directed forgetting, a domain that has been of considerable interest (see Titz & Verhaeghen, 2010, for a review). Although older adults recalled and recognized fewer R items than did younger adults, older adults retrieved more F items. This account derived from the widely cited *inhibitory deficit* account of aging (Hasher & Zacks, 1988), wherein attentional inhibition suppresses irrelevant information at encoding to reduce overloading of working memory. The idea is that older adults have difficulty inhibiting the processing of goal-irrelevant information—the F words. Consequently, a reduced DFE in older adults—stemming from their better memory for F items—has been explained as a deficit with age in inhibiting F items (Collette et al., 2009; Earles & Kersten, 2002; Hogge et al., 2008; Zacks et al., 1996).

A more recent explanation of aging-related memory deficits is the *associative deficit* account (Naveh-Benjamin, 2000): That older adults have a specific difficulty in binding (associating) information to context. In several studies, Naveh-Benjamin observed that, compared to younger adults, older adults consistently showed reduced associative memory performance, but their memory for single items was equivalent. This fits with the idea of older adults being deficient in forming associations between items but having intact memory for single items. Researchers continue to provide support for an associative deficit in aging (see Old & Naveh-Benjamin, 2008, for a review).

The associative deficit hypothesis potentially provides another account for performance differences between older and younger adults in an item-method-directed forgetting paradigm. To remember which cue (R or F) is to be applied to the most recently presented item, participants must *bind* or *associate* the appropriate cue to that item. Older adults may do so less successfully. One of our goals was to examine whether older adults' associative deficit might contribute to their relative inability to form item–cue associations, ultimately affecting their overall performance in a directed forgetting task.

On a source memory test, participants are typically asked to indicate the source of studied information (see Johnson et al., 1993, for a review), such as knowledge of when, where, or how something was learned. A consistent finding in the cognitive aging literature is that memory deficits in healthy older adults are larger for source memory than for item memory (see Spencer & Raz, 1995, for a review). In line with this, the associative deficit account of aging (Naveh-Benjamin 2000) suggests that older adults would have difficulty on source memory tests due to their deficit in remembering pairings. Applying this to directed forgetting, older adults might confuse the R items and F items, distorting their allocation of rehearsal. To examine whether an associative deficit is affecting performance in a directed forgetting task, we examined the performance of younger and older adults on a source memory test for item–cue pairing.

Experiment 1

The impetus for this project came from William E. Hockley's influential work on associative memory and directed forgetting. To examine whether an associative deficit might underlie performance in the item-method paradigm, we added a source memory test following the item recognition test. Studies have shown younger adults to be quite accurate in reporting the cue connected to a study item (Horton & Petruk, 1980; Thompson et al., 2011). Having incorporated a source memory task after a yes/no recognition task, MacLeod (1975) found that young participants quite successfully retained the appropriate R or F cue along with each studied item. Some studies have even suggested that forming these item–cue associations is an essential strategy to keep track of differential rehearsal processes that must be carried out following the instruction for an item (Bancroft et al., 2013; MacLeod, 1975; Woodward & Bjork, 1971).

In this first experiment, both older and younger adults were administered the standard study phase of item-method directed forgetting. In the first test phase, they completed a yes/no item recognition task. Then, in the second test phase, they were re-presented with each originally presented item and asked to determine whether it had been followed by an R cue or by an F cue. Based on Naveh-Benjamin's (2000) associative deficit account of aging, we expected younger adults to have better source memory than older adults, indicative of the older adults' associative deficit. This deficit would potentially cause older adults to have difficulty in forming item–cue associations, resulting in poorer discrimination of R items from F items during study and hence a reduced DFE on the recognition memory test.

Method

Participants

Forty-five young adults (ages 18–24; $M = 20.61$; $SD = 1.21$) and 43 older adults (ages 65–92; $M = 73.23$; $SD = 1.14$) were recruited on the basis of an a priori power analysis with a desired power of .80 ($\alpha = .05$) to detect an effect size of $d = .40$ (based on previous studies of aging using the item-method paradigm; Gallant & Yang, 2014; Sego et al., 2006). The data of two older adults were removed due to technical difficulties (final sample size: younger adult $n = 45$; older adult $n = 41$). Younger adults were from the University of Waterloo Psychology participant pool and took part for course credit. Older adults were from the Waterloo Research in Aging participant pool and received a $10 gift card as remuneration. This database consists of older adults residing in the university region, recruited via local advertising and public talks to seniors' groups. For inclusion in this database, they self-reported being healthy and free of stroke or any diagnosis of cognitive impairment. Age and sex of older adults were collected from the participant pool prescreen. Detailed demographic information for each age group is presented in Table 1. We also note that, due to the COVID-19 pandemic, older adults completed the Montreal Cognitive Assessment (MoCA) Blind/Telephone—Version 8.1, which required a passing score of 19 out of 22 (Wittich et al., 2010), indicating normal cognitive aging, and that they reported being free from major cognitive and neurological impairments. The study was approved by the University of Waterloo Research Ethics Board (REB no. 42083).

Materials

We created a master list of 200 common English words from the SenticNet four-word corpus (Cambria et al., 2016). Median word frequency was 552 (range: 258–764), median word length was 5 (range: 4–7), the mean number of morphemes was 1.40 ($SD = .51$), and the mean number of syllables was 2.04 ($SD = .75$). The study list consisted of 60 words. Two additional words at the beginning and two at the end of the list, all four given R cues, served as primacy and recency buffers; these were not included in analyses. Custom software embedded in the PsychoPy 3.0 program randomly assigned 30 words to the R condition and 30 to the F condition. This randomization was done, following instructions provided by Taylor, Quinlan, and Vullings (Taylor et al., 2018), separately for each participant before their session to ensure unique stimulus combinations across our conditions. All materials were presented in size 20 Times New Roman black font on a white screen. Words in the study and test phases were presented in lower case.

Procedure

The experiment was programmed using PsychoPy 3.0 software and conducted using remote conference tools (e.g., Webex). Younger adults participated using a desktop or laptop computer. Older adults were given the option to participate using their touchscreen tablet (e.g., Microsoft Surface, iPad). There was no difference in performance between older adults who used a computer and those who used a tablet.

Practice Phase. Participants were presented with sample R and F trials and were asked to explain to the researcher what each cue indicated. The researcher went over the instructions until they felt confident that the participant understood them.

Study Phase. Each trial began with a centered 1-s fixation point (+), followed by a centered word for 2 s. Each word was followed by a 3-s centered single-letter R or F cue. The next trial began immediately after the cue disappeared. Participants were told that their memory would be tested only for R items and that they should forget all items followed by F cues. Participants were also asked not to write down any words or say them aloud. To ensure compliance, the researcher remained on the video call for the duration of the experiment.

Test Phases. Immediately, following the study phase, the researcher provided both on-screen and oral instructions for each test phase. For the first test phase, the recognition test, participants were informed that—contrary to what they had been told before the study phase—they would be tested on both R and F words. The 120 test words—60 from the study phase and 60 randomly selected from the remaining words in the master list—were presented one at a time with participants told to press a key to indicate whether each word was old (the *z* key) or new (the *m* key).[2] For the second test phase, the source memory test, participants were shown each studied word and asked to report whether it had been paired at study with an R cue (the *r* key) or an F cue (the *f* key). On both tests, participants were to respond as accurately as possible, taking as long as needed, and no feedback was provided. Presentation order of test words was randomized anew for each participant on each test.

Table 1
Demographic Information and Cognitive Status Measures for Each Age Group and Experiment

Measures	Younger M (SD)	Older M (SD)
Experiment 1		
Sex (% female)	64	78
Age (years)	20.61 (1.21)	73.23 (1.14)
Education (years)[a]	14.47 (1.12)	16.32 (2.77)
Mill Hill Vocabulary score[b]	30.63 (2.65)	38.63 (2.91)
MoCA score[c]	—	20.76 (2.24)
Experiment 2		
Sex (% female)	71	71
Age (years)	25.60 (3.65)	71.92 (5.25)
Education (years)[a]	13.67 (1.52)	14.74 (2.89)
Mill Hill Vocabulary score[b]	31.56 (2.33)	46.32 (3.21)
Self-reported cognitive health	—	51.20 (4.32)

[a] Self-reported cognitive health was rated on a 5-point scale. Older adults had significantly more years of education and significantly higher Mill Hill scores than younger adults in both experiments. [b] Number correct on Set A of the Mill Hill Vocabulary Scale (Raven, 1958). [c] Number correct on the Montreal Cognitive Assessment (MoCA) Blind/Telephone—Version 8.1.

Results

Following Snodgrass and Corwin's (1988) two-high-threshold model, we calculated discrimination accuracy (P_r = hit rate − false alarm rate) and response bias (B_r = false alarm rate/(1−P_r)), and analyzed each separately. Data are available at https://osf.io/nv4yk/ (Tan et al., 2022).

Discrimination Accuracy

Mean P_r for R and F items for each age group, and their respective (FARs), are shown in Table 2. We performed a 2 (Age: younger vs. older) × 2 (cue: R vs. F) mixed analysis of variance (ANOVA) on P_r. A significant main effect of age confirmed that younger adults ($M = .54$, $SE = .03$) performed better overall than older adults ($M = .44$, $SE = .03$), $F(1, 83) = 5.07$, $MSE = .09$, $p = .027$, $\eta^2 = .37$, and a significant main effect of cue confirmed the expected DFE (for R, $M = .62$, $SE = .02$; for F, $M = .36$, $SE = .02$), $F(1, 83) = 182.23$, $MSE = .02$, $p < .001$, $\eta^2 = .24$. These main effects were qualified by a significant interaction, $F(1, 83) = 4.01$, $MSE = .02$, $p = .049$, $\eta^2 = .01$, in which the magnitude of the DFE was smaller for older adults than for younger adults.

A priori independent samples t tests were conducted to assess the age-related performance differences. For R items, younger adults

[2] Participants using a tablet were instructed to press the left side of the screen to indicate an old response and the right side to indicate a new response.

Table 2
Experiment 1: Mean Discrimination Accuracy (P_r Score), Recognition Bias (B_r Score), False Alarm Rate, and Directed Forgetting Effect Magnitude for Each Age Group

Age group	P_r score		B_r score			
	R	F	R	F	FAR	DFE
Younger	.69 (.03)	.39 (.03)	.36 (.02)	.19 (.02)	.11 (.04)	.30
Older	.55 (.04)	.33 (.04)	.38 (.03)	.25 (.03)	.13 (.06)	.22

Note. FAR = false alarm rate; DFE = directed forgetting effect; R = to-be-remembered; F = to-be-forgotten.

performed significantly better than older adults, $t(83) = 2.86$, $p = .005$, $d = .62$. For F items, younger and older adult performance did not differ significantly, $t(83) = 1.28$, $p = .204$, $d = .28$. We next calculated the magnitude of the DFE by subtracting the discrimination accuracy for F items from the discrimination accuracy for R items; these means are also included in Table 2. Independent samples *t* test showed that younger adults had a significantly larger DFE than older adults, $t(83) = 2.00$, $p = .049$, $d = .44$.

Response Bias

We also conducted a 2 (age: younger vs. older) × 2 (study cue: R vs. F) mixed ANOVA on recognition bias, B_r. Mean B_r scores are shown in Table 2, with higher scores indicating more liberal responding. Only the main effect of cue was significant, $F(1, 83) = 80.83$, $MSE = .98$, $p < .001$, $\eta^2 = .10$, with B_r scores higher for R items ($M = .37$, $SE = .03$) than for F items ($M = .22$, $SE = .02$). Neither the main effect of age nor the interaction was significant, both Fs $(1, 83) < 1$. A priori independent samples *t* tests revealed no significant effect on recognition bias but, in general, older adults had higher B_r scores than younger adults.

Source Attribution

A 2 (age: younger vs. older) × 2 (cue: R vs. F) mixed ANOVA on proportion of items assigned the correct cue revealed no difference in correct labeling of R versus F items, $F(1, 83) < 1$. There was a significant main effect of age, $F(1, 83) = 5.62$, $MSE = .03$, $p = .020$, $\eta^2 = .03$, with younger adults ($M = .72$, $SE = .02$) more accurate than older adults ($M = .66$, $SE = .02$). Although the interaction was not significant, $F(1, 83) = 2.54$, $MSE = .03$, $p = .115$, $\eta^2 = .02$, a priori independent samples *t* tests showed that, compared to older adults ($M = .64$, $SE = .02$), younger adults ($M = .74$, $SE = .02$) correctly labelled significantly more R items, $t(83) = 2.83$, $p = .006$, $d = .62$, whereas correct labeling of F items did not differ between the age groups (for older, $M = .67$, $SE = .02$; for younger, $M = .69$, $SE = .01$), $t(83) = .41$, $p = .680$, $d = .09$.

Discussion

Three principal findings emerged from Experiment 1. First, younger adults correctly recognized more items than older adults. This is in line with previous studies of aging and directed forgetting (Gallant & Yang, 2014; Gamboz & Russo, 2002; Hogge et al., 2008; Titz & Verhaeghen, 2010). Second, in contrast to Zacks et al.'s (1996) finding that older adults showed better recognition of F items than did younger adults, here older and younger adults' performance on F items did not differ. Our findings, therefore, provide no evidence to support an inhibitory mechanism that operates on F items at encoding and that functions more poorly in older adults. Third, older adults were less successful than younger adults at correctly identifying item–cue associations. The poorer source memory in older adults is consistent with our hypothesis that age-related differences in item-method-directed forgetting could arise from an associative deficit rather than from an inhibition deficit.

Experiment 2

Our proposal that an associative deficit in older adults could influence performance on a test of directed forgetting received some support in Experiment 1. Moreover, our results conflicted with those of Zacks et al. (1996), providing no evidence to support an inhibitory mechanism operating on F items at encoding, a mechanism that they proposed is deficient in older adults. Given these findings, we sought to conceptually replicate them in Experiment 2 in an online sample of participants, also increasing our sample size. We adopted the three-response source attribution test of Thompson et al. (2011): On a single test, participants were to identify each item as an R item, an F item, or a new item, replacing the two separate tests used in Experiment 1. This three-response task has been suggested as a better tool for investigating source attributions because it allows researchers to examine both correct source attributions and incorrect/missed source attributions (i.e., mislabeling a new item as an R or F item; Bancroft et al., 2013; Gallant & Yang, 2014; Thompson et al., 2011).

Method

Participants

Two hundred ten adults from Prolific (www.prolific.co), an online crowdsourcing platform for data collection, participated for 20 min in exchange for £3.75. The sample size was based on observing $d = .40$ for the difference in performance between R and F words. A sample of 100 would yield power greater than 0.90 to detect this effect, but we decided to double this because we wanted to investigate the interaction—the effect of age on the DFE in recognition memory. The data of four older adults were excluded because they indicated using external aids to remember the items during the task. One older adult was excluded due to software issues. Four younger adults were excluded because they switched tabs during the experiment multiple times, indicating distraction. The final sample therefore consisted of 201 participants—100 older adults and 101 younger adults. The inclusion criteria for older adults were: (a) native speaker of English, (b) approval rating of at least 90% on previous Prolific studies, and (c) age 60–100. The same inclusion criteria were used for younger adults with the exception that age was set as 18–30. The study was approved by University of Waterloo Research Ethics Board (REB no. 42083).

Detailed demographic information for each age group is presented in Table 1. In addition, because we could not administer the MoCA remotely, we substituted the Cognitive Difficulties Scale (CDS; McNair & Kahn, 1983) as an indicator of gross cognitive status in older adults. We used the revised version of the CDS from

Gass et al. (2021), removing the questions associated with sex-specific roles. Scores for all older adults fell in the average range (scores of 40–55 for the age range 60–70) for this test in this population (Gass et al., 2021).

Materials

Materials were identical to Experiment 1.

Procedure

Participants were recruited via Prolific and were directed to a separate website hosted on Pavlovia (www.pavlovia.org), where they ran the experiment independently. The study phase was identical to Experiment 1. The test phase, however, used the three-response recognition task instead of the two separate test phases used in Experiment 1. Participants were instructed to press a key to indicate whether, during the study phase, each test word had been paired with an R cue (the *v* key) or an F cue (the *b* key), or was a new word not shown during study (the *n* key). The test phase was again randomized and self-paced.

Results

Discrimination Accuracy

We again calculated P_r and B_r.[3] Means for R and F items for each age group, and the FAR, are shown in Table 3. We performed a 2 (age: younger vs. older) × 2 (cue: R vs. F) ANOVA on P_r. A significant main effect of age showed, surprisingly, that older adults ($M = .52$, $SE = .02$) actually performed better overall than younger adults ($M = .45$, $SE = .02$), $F(1, 199) = 7.21$, $MSE = .07$, $p = .008$, $\eta^2 = .02$. A significant main effect of cue confirmed the expected DFE (for R, $M = .59$, $SE = .01$; for F, $M = .38$, $SE = .01$), $F(1, 199) = 420.11$, $MSE = .01$, $p < .001$, $\eta^2 = .21$. The interaction was not significant, $F(1, 199) = 2.33$, $p = .129$.

A priori planned independent samples *t* tests were conducted to investigate the age difference. Older adults actually showed better recognition for both types of cue: for R items $t(199) = 3.02$, $p = .003$, $d = .43$, and for F items $t(199) = 1.99$, $p = .048$, $d = .28$. We calculated the magnitude of the DFE by subtracting P_r for F items from P_r for R items; these means are also included in Table 3. An independent samples *t* test showed that the size of the DFE did not differ between older and younger adults, $t(199) = 1.53$, $p = .129$, $d = .22$ (in keeping with the overall nonsignificant interaction).

Table 3

Experiment 2: Mean Discrimination Accuracy (P_r Score), Recognition Bias (B_r Score), False Alarm Rate, and Directed Forgetting Effect Magnitude for Each Age Group

Age group	P_r score		B_r score			
	R	F	R	F	FAR	DFE
Younger	.55 (.03)	.35 (.03)	.73 (.03)	.36 (.03)	.34 (.04)	.19
Older	.64 (.05)	.41 (.04)	.58 (.02)	.36 (.02)	.22 (.02)	.23

Note. FAR = false alarm rate; DFE = directed forgetting effect; R = to-be-remembered; F = to-be-forgotten.

Response Bias

We also conducted a 2 (age: young vs. old) × 2 (study cue: R vs. F) mixed ANOVA on B_r. Mean B_r scores are shown in Table 3. There was a significant main effect of cue, $F(1, 199) = 295.59$, $MSE = .02$, $p < .001$, $\eta^2 = .14$, where responding was more liberal for R items ($M = .65$, $SE = .02$) than for F items ($M = .44$, $SE = .02$). There also was a significant main effect of age, $F(1, 199) = 20.90$, $MSE = .12$, $p < .001$, $\eta^2 = .07$, demonstrating more liberal responding for younger adults ($M = .62$, $SE = .02$) than for older adults ($M = .47$, $SE = .02$). The interaction was not significant, $F(1, 199) < 1$. A priori independent samples *t* tests revealed that B_r scores of younger adults were higher than those of older adults both for R items, $t(199) = 3.98$, $p < .001$, $d = .56$, and for F items, $t(199) = 4.65$, $p < .001$, $d = .66$.

Source Attribution

Following Thompson et al. (2011), we calculated correct source attributions as the proportion of old items correctly labelled out of the number of items correctly recognized as old (e.g., R items labelled as "R"/[R items labelled as "R" or "F"]). A 2 (age: young vs. old) × 2 (study cue: R vs. F) mixed ANOVA on correct source attributions revealed a significant main effect of study cue: Participants more accurately labelled R items ($M = .83$, $SE = .01$) than F items ($M = .74$, $SE = .01$), $F(1, 199) = 38.98$, $MSE = .02$, $p < .001$, $\eta^2 = .07$. There was a marginally significant main effect of age, with younger adults ($M = .80$, $SE = .01$) showing slightly more accurate source attribution than older adults ($M = .77$, $SE = .01$), $F(1, 199) = 3.32$, $MSE = .04$, $p = .070$, $\eta^2 = .01$. The interaction was not significant, $F(1, 199) < 1$.

We conducted two independent samples *t* tests to further examine whether age affected correct source attribution. Although neither was significant, we present these because of our a priori hypothesis. Source attribution performance was slightly better for younger adults than for older adults both for R items (younger: $M = .85$, $SE = .01$; Older: $M = .82$, $SE = .02$), $t(199) = 1.39$, $p = .166$, $d = .20$, and for F items (younger: $M = .76$, $SE = .02$; older: $M = .72$, $SE = .02$), $t(199) = 1.52$, $p = .127$, $d = .22$. These findings are in the direction predicted by the associative deficit hypothesis but, as they were not significant, should not be overinterpreted.

We calculated source attributions to new items as the proportion of old responses (i.e., "R" or "F") made to new items out of the total number of new items called old (e.g., new items labelled as "R"/new items labelled as "R" or "F"). We then carried out a 2 (age: younger vs. older) × 2 (study cue: R vs. F) mixed ANOVA on the proportion of new items assigned an F label.[4] There was a main effect of study cue, $F(1, 199) = 442.83$, $MSE = .09$, $p < .001$, $\eta^2 = .65$, where new items received an F label ($M = .80$, $SE = .02$) much more often than an R label ($M = .17$, $SE = .01$). There was no main effect of age, $F(1, 199) < 1$. The interaction was, however, significant, $F(1, 199) = 8.32$, $MSE = .09$, $p = .004$, $\eta^2 = .01$.

[3] Note that saying either "F" or "R" to an item that was, in fact, presented at study (whether as an F item or as an R item) was considered a correct response here. This was done to separate recognition from source recall, as in Experiment 1.

[4] We did not analyze the proportion of new items assigned an R label because this is simply one minus the proportion of new items assigned an F label.

An independent samples t test showed that younger adults ($M = .85$, $SE = .02$) assigned "F" to new items significantly more often than did older adults ($M = .75$, $SE = .03$), $t(199) = 2.79$, $p = .006$, $d = .39$. In contrast, older adults gave significantly more R labels to new items ($M = .21$, $SE = .02$) than did younger adults ($M = .14$, $SE = .02$), $t(199) = 2.59$, $p = .010$, $d = .37$.

Discussion

Overall, both age groups demonstrated a DFE. In fact, though, older adults demonstrated better overall recognition than younger adults. This result suggests that a reduced DFE may be harder to detect in older adults when using online crowdsourcing platforms, as we did for this sample. In addition, younger adults showed a higher FAR than older adults, an age difference that is typically the opposite in the literature (e.g., Huh et al., 2006; Zacks et al., 1996). Our findings contradict previous studies (Gallant & Yang, 2014; Zacks et al., 1996) that have demonstrated a smaller DFE, lower hit rates, and lower FARs in older compared to younger adults. Our findings are in line, however, with a recent study of aging and directed forgetting that also used a sample from another online crowdsourcing platform, Mechanical Turk (Bowen et al., 2020). In that study, as in ours, older adults had higher corrected recognition scores for both R and F items, and lower FARs compared to younger adults. It is worth noting that relative to the group sizes of Zacks et al. (1996) ($n = 24$), the Bowen et al. (2020) sample sizes ($n = 48$) were twice as large, and our sample size was over four times larger ($n = 100$). Last, it is also possible that the results of Zacks et al. (1996) reflect age-related differences in an age cohort different from the one tested here. That is, the healthy older adults in our study are arguably more computer savvy than those in previous years and may also be less anxious about their performance (cf. stereotype threat; Barber & Lui, 2020). The COVID-19 pandemic may have forced this population to learn more computer skills and possibly eased their anxiety concerning computer-based psychology experiments, resulting in better overall memory performance (Martínez-Alcalá et al., 2021).

Our source attribution findings are consistent with the associative deficit hypothesis (Naveh-Benjamin, 2000). As in Experiment 1, older adults again were less accurate in identifying item–cue associations than were younger adults, although here the pattern was not statistically significant. The three-response source attribution test used here also showed that both younger and older adults were more accurate at identifying R items than they were at identifying F items. We also found an age-related difference in the labels that participants assigned to new items: Older adults assigned an R label to new items more commonly than younger adults, suggesting more difficulty in remembering the cues than was the case for younger adults, who assigned an F label to new items more commonly than did older adults.

Past work using the remember/know paradigm to measure recollective experience has shown that people often vividly remember events that never occurred, a phenomenon referred to as illusory recollection (Gallo & Roediger, 2003). The age-related increase in illusory recollection here is in line with past work (Skinner & Fernandes, 2009), suggesting that older adults are less able to use controlled processes during retrieval to successfully monitor lures and thus to correctly attribute feelings of familiarity (leading to their increase in R misattributions). For older adults, it is possible that more R items are weakly encoded, leading older adults to more often confuse R items with new items than younger adults do.

General Discussion

Past research has reported a smaller DFE in older adults than in younger adults (Collette et al., 2009; Dulaney et al., 2004; Titz & Verhaeghen, 2010; Zacks et al., 1996), deriving from older adults remembering more F items than younger adults do. According to Hasher and Zacks's (1988) inhibition account, this occurs because older adults are less able to inhibit the irrelevant F items during encoding, and consequently later recognize more F items than younger adults do. In Experiment 1, we found instead that older adults' performance was poorer than that of younger adults on R items but that there was no difference in their performance on F items. This overall poorer memory is consistent with the previously reported age-related memory decrement (Light, 1996), specifically in some directed forgetting studies (Gamboz & Russo, 2002; Hogge et al., 2008). In Experiment 2, though, we actually observed that older adults performed better than younger adults on the R items. We will discuss this difference between the two experiments later in this section.

In neither experiment did we observe better recognition of F items by older than by younger adults, contrary to Zacks et al. (1996). Because this has been the critical evidence relied on by the Hasher and Zacks (1988) inhibition account, our findings imply that age-related differences in item-method directed forgetting may be due to differences in processing of R items, not to differences in inhibition of F items. Younger adults may implement strategies used to encode R items more effectively, or older adults may use less effective encoding strategies.

This conclusion also fits with our observations concerning source judgments. Older adults were significantly less accurate than younger adults in identifying item–instruction associations, both for R and F items. Under an alternative theoretical account of aging—the associative deficit hypothesis (Naveh-Benjamin, 2000)—older adults have difficulty creating links and associating or binding items (Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). Consequently, older adults may be more likely to make errors in identifying the source of a memory. Given this associative deficit, we predicted that older adults would be less accurate on our source test at remembering which items had received an R cue versus an F cue at encoding. Compared to younger adults, older adults were indeed less accurate at assigning the correct cue to the studied items. This was significant in Experiment 1 but not in Experiment 2, although the pattern was in the same direction.

Critically, our directed forgetting results do not support an age-related deficit in directed forgetting performance that is driven by poorer F item performance. In fact, our Experiment 2 results demonstrated that older adults can perform better than younger adults in item-method-directed forgetting. Possibly, older adult samples from the Prolific pool have higher cognitive abilities (or are more computer savvy, or are less anxious, or are more motivated to participate in research) than were older adult samples in previous in-person laboratory studies. Previous studies have shown that there is a positive correlation between digital literacy and cognitive performance: Older adults with higher digital literacy and greater computer usage display higher cognitive performance (Klimova, 2016). Moreover, research on online younger adult populations has suggested that younger adults may be more distracted while completing studies using crowdsourcing platforms (Brown et al., 2014). Our results are consistent with this prior work.

In the end, two outcomes are clear from our study. First, contrary to past reports (Zacks et al., 1996), older adults in our experiments—using our methods—did not remember more to-be-forgotten items than did younger adults. This finding is inconsistent with accounts that suggest a role for inhibition in directed forgetting. Second, we found evidence that older adults indeed have difficulty, relative to younger adults, in associating the correct encoding cue (R or F) to previously studied items, consistent with an associative memory deficit (Naveh-Benjamin, 2000). We suggest an alternative account of age differences in directed forgetting: poorer encoding of relational information with increasing age.

Résumé

L'oubli intentionnel vise à empêcher que l'information non désirée soit stockée dans la mémoire à long terme. Étonnamment, des recherches antérieures ont montré que, comparativement aux jeunes adultes, les personnes âgées se rappellent et reconnaissent plus d'information à oublier. Il a été suggéré que cela est attribuable au fait que les personnes âgées ont une moins bonne capacité à inhiber l'information. Dans le cadre de deux expériences, nous avons examiné les différences entre la mémoire de jeunes adultes et personnes âgées au moyen d'un paradigme d'oubli dirigé en méthode item. On a présenté aux participants des mots un à la fois durant la phase d'étude, chacun étant suivi d'un indice pour se rappeler (R) le mot, ou pour l'oublier (F). Dans l'Expérience 1, on a évalué la reconnaissance des deux types de mots, parmi les participants, puis effectué un test de discrimination de source distinct pour l'indice qui était associé à chacun des mots. Dans l'Expérience 2, on a évalué la mémoire au moyen d'un test de reconnaissance à trois réponses, selon que le mot était nouveau ou avait été étudié, et s'il avait déjà été étudié, s'il était associé à l'indice R ou à l'indice F. Dans les deux expériences, les jeunes adultes et les personnes âgées ont reconnu plus de mots R que F, l'effet typique d'oubli dirigé. Contrairement, les adultes plus âgés ne se sont pas souvenus d'un plus grand nombre de mots F (à oublier) que les plus jeunes, ce qui ne correspond pas à un déficit d'inhibition. Toutefois, les personnes âgées étaient moins précises dans leur détermination des indices associés, à la fois pour les mots R et les mots F, ce qui correspond à un déficit de mémoire associative.

Mots-clés : oubli intentionnel, paradigme d'oubli dirigé en méthode item, vieillissement, inhibition

References

Bancroft, T. D., Hockley, W. E., & Farquhar, R. (2013). The longer we have to forget the more we remember: The ironic effect of postcue duration in item-based directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(3), 691–699. https://doi.org/10.1037/a0029523

Barber, S. J., & Lui, K. (2020). Stereotype threat and the cognitive performance of older adults. In A. K. Thomas & A. Gutchess (Eds.), *The Cambridge handbook of cognitive aging: A life course perspective* (pp. 400–416). Cambridge University Press. https://doi.org/10.1017/9781108552684.025

Bjork, R. A. (1972). Theoretical implications of directed forgetting. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp. 217–235). V. H. Winston.

Bowen, H. J., Gallant, S. N., & Moon, D. H. (2020). Influence of reward motivation on directed forgetting in younger and older adults. *Frontiers in Psychology*, *11*, Article 1764. https://doi.org/10.3389/fpsyg.2020.01764

Brown, H. R., Zeidman, P., Smittenaar, P., Adams, R. A., McNab, F., Rutledge, R. B., & Dolan, R. J. (2014). Crowdsourcing for cognitive science—The utility of smartphones. *PLOS ONE*, *9*(7), Article e100662. https://doi.org/10.1371/journal.pone.0100662

Cambria, E., Poria, S., Bajpai, R., & Schuller, B. (2016). *SenticNet 4: A semantic resource for sentiment analyses based on conceptual primitives* [Conference session]. Proceedings of COLING 2016, the 26th conference on computational linguistics: Technical papers, pp. 2666–2677.

Collette, F., Germain, S., Hogge, M., & Van der Linden, M. (2009). Inhibitory control of memory in normal ageing: Dissociation between impaired intentional and preserved unintentional processes. *Memory*, *17*(1), 104–122. https://doi.org/10.1080/09658210802574146

Dulaney, C. L., Marks, W., & Link, K. E. (2004). Aging and directed forgetting: Pre-cue encoding and post-cue rehearsal effects. *Experimental Aging Research*, *30*(1), 95–112. https://doi.org/10.1080/03610730490251504

Earles, J. L., & Kersten, A. W. (2002). Directed forgetting of actions by younger and older adults. *Psychonomic Bulletin and Review*, *9*(2), 383–388. https://doi.org/10.3758/BF03196297

Fawcett, J. M., & Taylor, T. L. (2008). Forgetting is effortful: Evidence from reaction time probes in an item-method directed forgetting task. *Memory and Cognition*, *36*(6), 1168–1181. https://doi.org/10.3758/MC.36.6.1168

Gallant, S. N., & Yang, L. (2014). Positivity effect in source attributions of arousal-matched emotional and non-emotional words during item-based directed forgetting. *Frontiers in Psychology*, *5*, Article 1334. https://doi.org/10.3389/fpsyg.2014.01334

Gallo, D. A., & Roediger, H. L., III. (2003). The effects of associations and aging on illusory recollection. *Memory and Cognition*, *31*(7), 1036–1044. https://doi.org/10.3758/BF03196124

Gamboz, N., & Russo, R. (2002). Evidence for age-related equivalence in the directed forgetting paradigm. *Brain and Cognition*, *48*(2–3), 366–371. https://doi.org/10.1006/brcg.2001.1379

Gass, C. S., Patten, B., Penate, A., & Rhodes, A. (2021). The Cognitive Difficulties Scale (CDS): Psychometric characteristics in a clinical referral sample. *Journal of the International Neuropsychological Society*, *27*(4), 351–364. https://doi.org/10.1017/S1355617720001058

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). Academic Press.

Hogge, M., Adam, S., & Collette, F. (2008). Directed forgetting and aging: The role of retrieval processes, processing speed, and proactive interference. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *15*(4), 471–491. https://doi.org/10.1080/13825580701878065

Horton, K. D., & Petruk, R. (1980). Set differentiation and depth of processing in the directed forgetting paradigm. *Journal of Experimental Psychology: Human Learning and Memory*, *6*(5), 599–610. https://doi.org/10.1037/0278-7393.6.5.599

Huh, T. J., Kramer, J. H., Gazzaley, A., & Delis, D. C. (2006). Response bias and aging on a recognition memory task. *Journal of the International Neuropsychological Society*, *12*(1), 1–7. https://doi.org/10.1017/S1355617706060024

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, *114*(1), 3–28. https://doi.org/10.1037/0033-2909.114.1.3

Klimova, B. (2016). Computer-based cognitive training in aging. *Frontiers in Aging Neuroscience*, *8*, Article 313. https://doi.org/10.3389/fnagi.2016.00313

Light, L. L. (1996). Memory and aging. In E. L. Bjork & R. A. Bjork (Eds.), *Memory* (pp. 443–490). Academic Press. https://doi.org/10.1016/B978-012102570-0/50015-X

MacLeod, C. M. (1975). Long-term recognition and recall following directed forgetting. *Journal of Experimental Psychology: Human Learning and Memory*, *1*(3), 271–279. https://doi.org/10.1037/0278-7393.1.3.271

MacLeod, C. M. (1998). Directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 1–57). Lawrence Erlbaum.

Martínez-Alcalá, C. I., Rosales-Lagarde, A., Pérez-Pérez, Y. M., Lopez-Noguerola, J. S., Bautista-Díaz, M. L., & Agis-Juarez, R. A. (2021). The effects of COVID-19 on the digital literacy of the elderly: Norms for digital inclusion. *Frontiers in Education*, *6*, Article 716025. https://doi.org/10.3389/feduc.2021.716025

McNair, D. M., & Kahn, R. J. (1983). Self-assessment of cognitive deficits. In T. Crook, S. Ferris, & R. Bartus (Eds.), *Assessment in geriatric psychopharmacology* (pp. 119–136). Mark Powley.

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*(5), 1170–1187. https://doi.org/10.1037/0278-7393.26.5.1170

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging*, *23*(1), 104–118. https://doi.org/10.1037/0882-7974.23.1.104

Raven, J. C. (1958). *Guide to using the Mill Hill Vocabulary Scale with the Progressive Matrices Scales*. H. K. Lewis.

Sego, S. A., Golding, J. M., & Gottlob, L. R. (2006). Directed forgetting in older adults using the item and list methods. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *13*(1), 95–114. https://doi.org/10.1080/138255890968682

Skinner, E. I., & Fernandes, M. A. (2009). Illusory recollection in older adults and younger adults under divided attention. *Psychology and Aging*, *24*(1), 211–216. https://doi.org/10.1037/a0014177

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*(1), 34–50. https://doi.org/10.1037/0096-3445.117.1.34

Spencer, W. D., & Raz, N. (1995). Differential effects of aging on memory for content and context: A meta-analysis. *Psychology and Aging*, *10*(4), 527–539. https://doi.org/10.1037/0882-7974.10.4.527

Tan, P., Ensor, T. M., Hockley, W. E., Harrison, G. W., & Wilson, D. E. (2020). In support of selective rehearsal: Double-item presentation in item-method directed forgetting. *Psychonomic Bulletin and Review*, *27*(3), 529–535. https://doi.org/10.3758/s13423-020-01723-w

Tan, P., Fernandes, M. A., & MacLeod, C. M. (2022, January 24). *Aging and directed forgetting: Evidence for an associative deficit but no evidence for an inhibition deficit*. osf.io/nv4yk

Taylor, T. L., Quinlan, C. K., & Vullings, K. C. H. (2018). Decomposing item-method directed forgetting of emotional pictures: Equivalent costs and no benefits. *Memory & Cognition*, *46*(1), 132–147. https://doi.org/10.3758/s13421-017-0751-y

Thompson, K. M., Fawcett, J. M., & Taylor, T. L. (2011). Tag, you're it: Tagging as an alternative to yes/no recognition in item method directed forgetting. *Acta Psychologica*, *138*(1), 171–175. https://doi.org/10.1016/j.actpsy.2011.06.001

Titz, C., & Verhaeghen, P. (2010). Aging and directed forgetting in episodic memory: A meta-analysis. *Psychology and Aging*, *25*(2), 405–411. https://doi.org/10.1037/a0017225

Wittich, W., Phillips, N., Nasreddine, Z. S., & Chertkow, H. (2010). Sensitivity and specificity of the Montreal Cognitive Assessment modified for individuals who are visually impaired. *Journal of Visual Impairment and Blindness*, *104*(6), 360–368. https://doi.org/10.1177/0145482X1010400606

Woodward, A. E., & Bjork, R. A. (1971). Forgetting and remembering in free recall: Intentional and unintentional. *Journal of Experimental Psychology*, *89*(1), 109–116. https://doi.org/10.1037/h0031188

Zacks, R. T., Radvansky, G., & Hasher, L. (1996). Studies of directed forgetting in older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(1), 143–156. https://doi.org/10.1037/0278-7393.22.1.143

Received January 24, 2022
Revision received June 27, 2022
Accepted June 27, 2022 ■