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Authors

Castel, Alan

Murphy, Dillon

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Differential Effects of Proactive and Retroactive Interference in Value-Directed Remembering for Younger and Older Adults

Dillon H. Murphy,

Alan D. Castel

Department of Psychology, University of California Los Angeles

Abstract

We are often presented with more information than we can remember, and we must selectively focus on the most valuable information to maximize memory utility. Most tests of value-based memory involve encoding and then being tested on a list of recently studied information. Thus, people are focused on memory for the current list and are encouraged to forget information from earlier lists. However, prior learning can influence later memory, in both interfering and beneficial ways, and there may be age-related differences in how younger and older adults are influenced by the costs and benefits of prior learning and interference. In the current study, we presented younger and older adults with words paired with point values to remember for a later test but rather than asking participants to only recall words from the just-studied list, participants were asked to recall all studied words on each recall test. Results revealed that younger adults were more likely to recall words from previous lists than older adults, indicating that older adults were more susceptible to retroactive interference. Moreover, although selectivity is often preserved in older adults when study-test cycles are independent, a buildup of proactive interference arising from previously studied words reduced memory selectivity in older adults. Thus, when presented with more information than one can remember, younger adults are better at combating interference and recalling valuable information, while older adults may engage in selective forgetting of prior lists to enhance a "present-focused" form of memory, possibly as a result of impaired inhibitory control.

Keywords

value-directed remembering; proactive interference; retroactive interference; aging; selectivity

We are often presented with large amounts of information to remember like names, birthdays, items to buy at the grocery store, and work deadlines, just to name a few. Day after day, we must remember this information and, with each passing day, we accumulate more and more information to remember. For example, in the classroom, students are presented with information to remember multiple days each week, for several months, and must remember this information for both minor assessments throughout the semester and major assessments like midterms and finals. Additionally, we often must update information,

Please address correspondence to Dillon H. Murphy, Department of Psychology, University of California, Los Angeles, Los Angeles, CA 90095, dmurphy8@ucla.edu.

such as items to buy at the grocery store today as opposed to last week. However, most prior work investigating memory for important information using value-based memory tasks has focused on tests for a single set of information and then again for new sets of information (independent of any previously studied information).

When presented with more information than we can remember, focusing on the most valuable or important information can be crucial in maximizing memory utility and preventing negative consequences for forgetting (e.g., Murphy & Castel, 2020, 2021a, 2021b, 2022b; Murphy et al., 2022). To examine memory for valuable or important information, prior work has presented learners with lists of words paired with point values counting towards their task scores if recalled (e.g., Castel et al., 2002). These value-directed remembering tasks illuminate how learners use value to guide encoding and retrieval processes by measuring memory capacity (number of words recalled) and selectivity (the recall of high-value items relative to low-value items). Generally, learners tend to focus more on high-value information and less on low-value information to maximize gains, illustrating memory selectivity (e.g., Ariel et al., 2009; Soderstrom & McCabe, 2011; see Knowlton & Castel, 2022; Madan, 2017 for a review).

In most prior work examining how value influences memory, learners are presented with a list of information to remember, tested on that list, then presented with a new list of information to remember for the next test (i.e., after studying and being tested on a list of words, if participants study another list of words, they are usually tested on their memory for just the second list, not information from both lists). However, using such a list-by-list design (with recall of only the current list being assessed) does not allow for direct observations of value-based interference effects on memory. Thus, this design and procedure do not allow for a direct investigation of how prior learning influences current recall performance and does not reveal whether participants still have access to previously studied high-value information on later tests of memory (see Castel et al., 2007). Specifically, in these paradigms, once learners are tested on a list of information, they no longer need to remember it for the next list, but we usually need to remember previously learned important information as well as new information that is valuable and update the information accordingly in memory.

When learning new information after learning other information, memory for previously learned information may interfere with the learning of new information, a process known as proactive interference (Underwood, 1957). Additionally, learning new information may interfere with memory for previously learned information, known as retroactive interference (Tulving & Psotka, 1971). Applied to value-directed remembering, memory for previously studied lists may interfere with a learner’s ability to encode vital information on the present list they are studying, or the encoding of a new list of information may disrupt memory for valuable items from previous lists. Thus, proactive and/or retroactive interference could result in the forgetting of valuable information, or less access to high-value information, if lower value information is “cluttering” memory, particularly in older adults (cf., Amer et al., 2022).

Most learners can selectively remember important items on each list of information, even at an older age. For example, although older adults generally experience cognitive declines as a product of normal aging (see Hess, 2005; Park & Festini, 2017; Salthouse, 2010, 2019; Thomas & Gutchess, 2020), older adults can still remember valuable information at the expense of low-value information (e.g., Castel et al., 2012, 2013; McGillivray & Castel, 2011; Middlebrooks et al., 2016). However, older adults may be more susceptible to proactive and retroactive interference (Hasher et al., 2002; Hay & Jacoby, 1999; Jacoby et al., 2010; Solesio-Jofre et al., 2012). Thus, prior list learning could influence current performance and there may be important age-related differences in the ability to both forget and retrieve once-relevant information.

In the context of direct forgetting (intentional or goal-directed forgetting of certain information), after studying a list of information, both younger and older adults can forget information if they are instructed to forget it (e.g., Biss et al., 2013; Bowen et al., 2020; Murphy & Castel, 2022b; Sahakyan et al., 2008; Sego et al., 2006; Zacks et al., 1996; and see Titz & Verhaeghen, 2010 for a meta-analysis), suggesting that some forms of strategic forgetting are intact in older age (but may be impaired in older-old adults over the age of 75; see Aslan & Bauml, 2013). This mechanism of strategic or adaptive forgetting reduces interference in some situations, although it is unclear how this may differentially influence memory for lower and higher value information (but see Bowen et al. (2020) for a demonstration of how financial reward anticipation can boost younger and older adults' memory for both to-be-remembered and to-be-forgotten items in a directed forgetting task, indicating that high values can strengthen memory without enhancing strategic control over memory). Thus, it is important to understand how younger and older adults strategically prioritize memory for valuable information when learning and recalling information in an ongoing basis, and when earlier information can be important to recall on later tests of memory.

The Current Study

In the current study, we presented younger and older adults with lists of words paired with point values to remember (participants' task scores were the sum of the point values of recalled words and their task was to maximize their point scores on each list). First, in Experiment 1, each study-test cycle was independent such that each recall test covered only the just-studied words (i.e., not words from previous lists). We sought to establish the general effects of value (high-value words are better recalled than low-value words) and age (older adults are similarly selective for high-value words as younger adults) on memory as seen in prior work (e.g., Castel et al., 2002) given our specific task parameters and in an online sample. Thus, Experiment 1 aimed to demonstrate how younger and older adults prioritize memory for valuable items when battling proactive interference during the encoding and retrieval of each new list.

In Experiment 2, rather than asking participants to only recall words from the just-studied list on each test (whereby learners are only afflicted by proactive interference), we asked participants to recall all studied words on each recall test (whereby learners also experience retroactive interference). Thus, on later lists, participants could score more points by recalling words from all previously studied lists as well as the just-studied list. We expected both younger and older adults' recall to be driven by value such that they prioritize memory for high-value words at the expense of low-value words, especially when recalling words from previously studied lists. However, because older adults may be more susceptible to interference (Hasher et al., 2002; Solesio-Jofre et al., 2012), we expected more forgetting of high-value words from previously studied lists in older adults. Additionally, as the number of words that could potentially be recalled on each list grows, the relative value of remembering low-value words steadily decreases. As a result, we expected participants to forget low-value words (especially from more distant lists) as these items do relatively little to increase their task performance.

Experiment 1

Prior work has shown that despite memory impairments, older adults can selectively focus on remembering important information (see Castel, 2008). In Experiment 1, we aimed to replicate and extend this prior work in an online sample, further establishing that younger and older adults' recall is sensitive to word value and that selectivity for high-value words is preserved in older adults (e.g., Castel et al., 2002, 2007). In addition, we wanted to examine how this effect changes on later lists (see Castel et al., 2012) as increased task experience can reduce or eliminate age-related differences in memory for high-value information when participants are tested for information on the most recent list (the standard paradigm used in most studies of value-directed remembering, e.g., Castel et al., 2002; Murphy et al., 2021; Murphy & Castel, 2022a; see Knowlton & Castel, 2022; Madan, 2017 for a review), although the role of interference has not been examined in this context.

Critically, in this standard value-directed remembering task, people are rewarded for recalling words from the current list (but not from words from earlier lists), making it beneficial to avoid proactive interference by forgetting words from earlier lists. Some prior work suggests that for both younger and older adults, this "forgotten" information (words not recalled after each list) may still be activated when given a surprise final recognition test such that both younger and older adults may recognize words that were not initially recalled (Castel et al., 2007). Thus, this suggests that participants may be selectively recalling the current list as instructed, but earlier words are not entirely forgotten. In the present task, a strategic forgetting mechanism may be intact and used successfully by both younger and older adults to achieve memory selectivity (cf., Sahakyan et al., 2008). Specifically, despite potential proactive inference being greatest on later lists, task experience may allow both younger and older adults to overcome the increasing interference to achieve selectivity on later lists (i.e., participants' recall may become more sensitive to value on later lists compared with earlier lists).

Method

Transparency and Openness.—We report an analysis of our sample size, describe all data exclusions, manipulations, and all measures in the study. All data and research materials are available on OSF. Data were analyzed using JASP and Jamovi, and all information needed to reproduce the analyses is available. This study's design and its analysis were not pre-registered. Informed consent was acquired and the study was completed in accordance with the UCLA Institutional Review Board.

Participants.—Younger adults (n = 79; M_{age} = 20.85, SD_{age} = 2.75; 61 female, 18 male; 39 Asian/Pacific Islander, 3 Black, 17 Hispanic, 15 White, 5 other/unknown) were recruited from the University of California Los Angeles (UCLA) Human Subjects Pool, were tested online, and received course credit for their participation. Older adults (n = 68; M_{age} = 74.29, SD_{age} = 6.19; 41 female, 27 male; 3 Black, 64 White, 1 other/unknown) were recruited from Amazon's Cloud Research (Chandler et al., 2019), a Web site that allows users to complete small tasks for pay. Participants were excluded from analysis if they admitted to cheating (e.g., writing down answers) in a post-task questionnaire (they were told they would still receive credit if they cheated). This exclusion process resulted in one exclusion from the younger adult group and three exclusions from the older adult group. The sample size was selected based on prior exploratory research and the expectation of detecting a medium effect size. A sensitivity analysis indicated that, with this sample size, an actual correlation of r = .63 between repeated measures, assuming alpha = .05, we had an 80% chance of detecting a *small* (Cohen's d = .15) interaction between age and list.

Materials and Procedure.—Participants were told that they would be presented with six lists of to-be-remembered words with each list containing 12 words. On each list, each word was paired with a unique, randomly assigned value between 1 and 12 indicating how much the word was "worth." Each point value was used only once within each list and the order of the point values within lists was randomized. The stimulus words were presented for 3 seconds each with a 500ms inter-stimulus interval. The words on each list were randomly selected from a pool of 280 unrelated words (e.g., button, chart, twig) that were between 4 and 7 letters (M = 4.99, SD = .98). On the log-transformed Hyperspace Analogue to Language frequency scale (with lower values indicating lower frequency in the English language and higher values indicating higher frequency), words ranged from 5.48-12.65 and averaged a score of 8.81 (SD =1.57). In terms of concreteness (with lower values indicating lower concreteness and higher values indicating higher concreteness), words ranged from 2.50-5.00 and averaged a score of 4.52 (SD = .46). Frequency and concreteness ratings were generated using the English Lexicon Project website (Balota et al., 2007).

Participants were told that they would score points for recalling words on the test and that they should try to maximize their scores. After the presentation of all 12 word-number pairs in each list, participants were given a 1-minute free recall test in which they had to recall as many words as they could from the just-studied list (they did not need to recall the point values). Participants recalled words by typing them into an on-screen text box. To account for typographical errors in participants' responses, we employed a real-time textual similarity algorithm where responses with at least 75% similarity to the correct answer were counted as correct. Immediately following the recall period, participants were told their score for that list but were not given feedback about specific items. This procedure was repeated for a total of six study-test trials.

Results

We first examined recall performance as a function of age and list. Specifically, a 2 (age: young, old) x 6 (test number) mixed ANOVA revealed that younger adults recalled more words throughout the task (M = 40.14, SD = 10.59) than older adults (M = 30.74, SD = 12.43), [F(1, 145) = 24.54, p < .001, η_p^2 = .15]. However, Mauchly's test of sphericity indicated violations for list [Mauchly's W = .73, p < .001] but Huynh-Feldt corrected results revealed a main effect of list [F(4.54, 657.60) = 3.13, p = .011, η_p^2 = .02] and list interacted with age [F(4.54, 657.60) = 6.23, p < .001, η_p^2 = .04] such that older adults' (but not younger adults') recall improved on later lists.

Next, we looked at potential age-related differences in intrusion rates. In Experiment 1, we classified two types of illusions: previous list intrusions (recalling a word that was studied on a prior list) and extra list intrusions (recalling a word that was not presented). An independent samples t-test revealed that, throughout the experiment, older adults committed more previous list intrusions (M = .87, SD = 1.40) than younger adults (M = .37, SD = .64), [Levine's test of equality of variances: p < .001, Welch's t-test: t(90.95) = 2.71, p = .008, d = .46], indicating that older adults were more susceptible to proactive interference. However, older adults committed a similar number of extra list intrusions (M = 2.34, SD = 2.76) as younger adults (M = 1.67, SD = 2.17), [Levine's test of equality of variances: p = .046, Welch's t-test: t(126.25) = 1.61, p = .110, d = .27].

To examine differences in selectivity for valuable information, we computed multilevel models (MLMs) where we treated the data as hierarchical or clustered (i.e., multilevel) with items nested within individual participants. Since recall at the item level was binary (correct or incorrect), we conducted logistic MLMs. In these analyses, the regression coefficients are given as logit units (i.e., the log odds of correct recall). We report exponential betas (e^B), and their 95% confidence intervals ($CI_{95\%}$), which give the coefficient as an odds ratio (i.e., the odds of correctly recalling a word divided by the odds of not recalling a word). Thus, e^B can be interpreted as the extent to which the odds of recalling a word changed. Specifically, values greater than 1 represent an increased likelihood of recall while values less than 1 represent a decreased likelihood of recall.

To examine memory selectivity (see Figure 1a and Figure 1b for recall as a function of age and value on earlier versus later lists), we conducted a logistic MLM with item-level recall modeled as a function of value and list with age (young, old) as a between-subjects factor. Results revealed that value significantly predicted recall [e^B = 1.11, $CI_{95\%}$ = 1.10 – 1.13, z = 17.20, p < .001] such that high-value words were better recalled than low-value words. Additionally, age significantly predicted recall [e^B = 1.78, $CI_{95\%}$ = 1.39 – 2.26, z = 4.62, p < .001] such that younger adults recalled more words than older adults. List also predicted recall [e^B = 1.04, $CI_{95\%}$ = 1.01 – 1.06, z = 2.78, p = .005] such that recall increased on later lists. However, value did not interact with age [e^B = 1.01, $CI_{95\%}$ = .99 – 1.04, z = .80, p = .425] such that younger and older adults were similarly selective. Age interacted with list [e^B = .90, $CI_{95\%}$ = .85 – .94, z = −4.46, p < .001] such that recall increased with task experience in older adults but not in younger adults. Value interacted with list [e^B = 1.02, $CI_{95\%}$ = 1.01 – 1.02, z = 4.54, p < .001] such that participants became more selective with increased task experience. Finally, there was not a three-way interaction between value, age, and list [e^B = .99, $CI_{95\%}$ = .98 – 1.00, $z = -1.47$, p = .141] such that younger and adults were similarly selective throughout the task.

Discussion

In Experiment 1, we replicated previous work (e.g., Castel et al., 2002; Murphy & Castel, 2022a; see Knowlton & Castel, 2022; Madan, 2017 for a review) such that both younger and older adults recalled high-value words at the expense of low-value words. Thus, both younger and older adults were able to overcome proactive interference and forget earlier lists to focus on performance on the current list, which may be recruit mechanisms similar to those used in directed forgetting (see Bäuml et al., 2020; Sahakyan et al., 2013; Johnson, 1994; MacLeod, 1998 for reviews). However, it remains unclear how learners' memory is influenced by value in the presence of retroactive interference when words from earlier lists become relevant and important to remember.

Experiment 2

In Experiment 1, we found that both younger and older adults could strategically focus on remembering words from the most recently presented list, consistent with prior work (e.g., Castel et al., 2002). In Experiment 2, we examined how this ability may be influenced by the addition of retroactive interference when words from earlier lists become relevant for current performance. To examine this issue, we developed a novel modification of the standard selectivity task in which younger and older adults studied six lists of words paired with point values, with each list containing 12 words. However, unlike Experiment 1 where each recall test was based only on the current list, participants' scores in Experiment 2 could be influenced by recalling words from earlier lists. Specifically, on each test, participants were told that they could recall words from both the current list as well as all prior lists, such that, for example, on List 3, participants could recall words from Lists 1, 2, and 3 to earn points.

We expected that although participants may remember many words from the just-studied lists, as the task continues and they learn new words, memory for words recalled on earlier lists likely declines on later recall tests as a result of retroactive interference. However, memory for valuable words on previous lists may be preserved as a strategy to maximize task performance. Despite prior work suggesting that memory selectivity is preserved in older adults (Castel et al., 2012, 2013; McGillivray & Castel, 2011; Middlebrooks et al., 2016), this addition of retroactive interference may diminish older adults' selective memory (Hasher et al., 2002; Solesio-Jofre et al., 2012).

Method

Participants.—Younger adults (n = 71; M_{age} = 19.86, SD_{age} = 2.26; 55 female, 16 male; 1 American Indian/Alaskan Native; 36 Asian/Pacific Islander, 1 Black, 13 Hispanic, 15 White, 5 other/unknown) were recruited from the UCLA Human Subjects Pool, were tested online, and received course credit for their participation. Older adults (n = 60; M_{age} = 71.58, SD_{age} = 5.11; 42 female, 18 male; 2 Asian/Pacific Islander, 1 Hispanic, 57 White) were recruited from Amazon's Cloud Research. Participants were excluded from analysis if they admitted to cheating (e.g., writing down answers) in a post-task questionnaire (they were told they would still receive credit if they cheated). This exclusion process resulted in zero exclusions from the younger adult group and 17 exclusions from the older adult group. A sensitivity analysis indicated that, with this sample size, an actual correlation of $r = .76$ between repeated measures, assuming alpha = .05, we had an 80% chance of detecting a *small* (Cohen's $d = .13$) interaction between age and list.

Materials and Procedure.—The task in Experiment 2 was similar to Experiment 1 except that on each recall test, participants were asked to recall as many words as they could from the just-studied list as well as all previous lists. For example, on List 3, participants were asked to recall words from Lists 1, 2, and 3 (i.e., participants could recall words from any studied list to earn points). Thus, it was made clear to participants that words from the current and any earlier list would contribute to their score and that they could recall the words in any order.

Results

We first examined the number of words recalled (any presented word on any list) as a function of age and test number. Specifically, a 2 (age: young, old) x 6 (test number) mixed ANOVA revealed that younger adults recalled more words throughout the task ($M = 68.04$, $SD = 26.99$) than older adults ($M = 42.17$, $SD = 15.92$), [$F(1, 129) = 42.61$, $p < .001$, $\eta_p^2 = .25$]. Additionally, there was a main effect of test number [Mauchly's $W = .11$, $p < .001$; Huynh-Feldt corrected results: $F(2.30, 296.73) = 90.43$, $p < .001$, $\eta_p^2 = .41$] and test number interacted with age [$F(2.30, 296.73) = 19.58$, $p < .001$, $\eta_p^2 = .13$] such that more words were recalled with each subsequent list but more so in younger adults.

To examine whether the words younger and older adults recalled on each list came from the just-studied list or prior lists, we conducted a 2 (age: young, old) x 2 (list source: current, previous) x 5[1] (test number) mixed ANOVA on recall performance. Results revealed that participants recalled more words from current lists than previous lists [$F(1, 129) = 31.25$, $p < .001$, $\eta_p^2 = .15$]. Additionally, list source interacted with age [$F(1, 129) = 31.25$, $p < .001$, $\eta_p^2 = .20$] such that younger adults recalled more words from previous lists than older adults [$p_{holm} > .001$]. Test number interacted with list source [Mauchly's $W = .50$, $p < .001$; Huynh-Feldt corrected results: $F(3.10, 399.96) = 44.93$, $p < .001$, $\eta_p^2 = .26$] such that the recall of previous list items increased on later tests. Finally, there was a three-way interaction between age, test number, and list source [$F(3.10, 399.96) = 19.05$, $p < .001$, $\eta_p^2 = .13$] such that younger adults were more likely to recall previous list words on later tests than older adults (see Figure 2). Specifically, as illustrated in Figure 3 which presents a breakdown of the origin of each word recalled on each test, younger adults' recall was composed of both current and prior list material relative to older adults, whose recall was almost exclusively composed of words from the most current list material.

Next, we looked at potential age-related differences in intrusion rates. Since participants could recall words from prior lists (and were encouraged to do so), we only examined extra list intrusions in Experiment 2 (i.e., there were no "previous list intrusions"). An

[1]We did not include List 1 because participants could not have recalled a word from a previous list on the first test.

independent samples *t*-test revealed that, across all recall tests, older adults committed a similar number of extra list intrusions ($M = 2.08$, $SD = 6.32$) as younger adults ($M = 2.38$, $SD = 3.12$), [$t(129) = .35$, $p = .728$, $d = .06$].

We were also interested in how participants organized their retrieval of the words from current and prior lists. We hypothesized that participants recall current-list words before prior-list words to reduce the buildup of proactive interference. To examine participants' recall, we calculated the average output position of words from the just-studied list and words from previous lists[2]. A 2 (age: young, old) x 2 (list source: current, previous) mixed ANOVA revealed that words from the current list were recalled in an earlier output position ($M = 4.26$, $SD = 1.33$) than words from previous lists ($M = 8.23$, $SD = 3.33$), [$F(1, 109) = 305.20$, $p < .001$, $\eta_p^2 = .74$]. Additionally, there was a main effect of age [$F(1, 109) = 36.00$, $p < .001$, $\eta_p^2 = .25$] and list source interacted with age [$F(1, 109) = 30.32$, $p < .001$, $\eta_p^2 = .27$] such that the average output position for current-list words was similar for younger and older adults but prior list words were outputted much later by younger adults compared with older adults [$p_{holm} < .001$], although this may be due to the increased recall of prior list words in younger adults.

To examine memory selectivity throughout the task (note that this analysis includes recall for each word on all previously studied lists on each test, giving each participant 252 cells; for example, the 12 words on List 1 could be recalled 6 times, the 12 words on List 2 could be recalled 5 times, etc.), we conducted a logistic MLM with item-level recall modeled as a function of value with age (young, old) as a between-subjects factor. Results revealed that value significantly predicted recall [$e^B = 1.08$, $CI_{95\%} = 1.08 – 1.09$, $z = 19.53$, $p < .001$] such that high-value words were better recalled than low-value words. Additionally, age significantly predicted recall [$e^B = 1.83$, $CI_{95\%} = 1.52 – 2.19$, $z = 6.51$, $p < .001$] such that younger adults recalled more words than older adults. Critically, value interacted with age [$e^B = 1.05$, $CI_{95\%} = 1.04 – 1.07$, $z = 6.28$, $p < .001$] such that value was a stronger predictor of recall for younger adults than older adults (see Figure 4).

Next, we examined how memory selectivity was affected by proactive interference. Specifically, rather than in Experiment 1 when previously studied information is no longer relevant once initially recalled, in Experiment 2, learners needed to retain previously studied information for future tests. Thus, to examine selectivity when affected by proactive interference, we examined memory selectivity only for words participants had just studied (i.e., List n). In this analysis, we only included the recall of words from the current list (e.g., the recall of List 3 words on the List 3 test). In light of the proactive interference from previously studied words, we expected younger adults to remember more high-value words from List n than older adults. A logistic MLM with item-level recall modeled as a function of value with age (young, old) as a between-subjects factor revealed that value significantly predicted recall [$e^B = 1.14$, $CI_{95\%} = 1.13 – 1.16$, $z = 19.81$, $p < .001$] such that high-value words were better recalled than low-value words. However, age did not significantly predict recall [$e^B = 1.10$, $CI_{95\%} = .82 – 1.49$, $z = .63$, $p = .530$] such that younger and older adults

[2]We note that although each participant serves as their own control in the present analysis (average output position of current list words versus prior list words), this metric may be biased by the number of outputted items.

recalled a similar number of current-list words. Critically, value interacted with age [e^B = 1.09, $CI_{95\%}$ = 1.06 – 1.11, $z = 6.09$, $p < .001$] such that value was a stronger predictor of recall for younger adults than older adults for words from List n (see Figure 5a).

To elucidate how memory selectivity is affected by retroactive interference, we examined recall for only the words participants had studied on the previous list (i.e., List n – 1). Specifically, in this analysis, we only included the recall of words that had been studied one list prior to the current list (e.g., the recall of words from List 5 during the List 6 test). Examining the recall of words from List n – 1 allows us to examine how the retroactive interference from the just-studied list impacts selective memory for previously studied words. We decided to look at just the recall of words from List n – 1 since the interference from the prior list should be more direct/recent and also equates the amount of material tested (looking at all earlier lists would include different numbers of words for different lists). A logistic MLM with item-level recall modeled as a function of value with age (young, old) as a between-subjects factor revealed that value significantly predicted recall [e^B = 1.09, $CI_{95\%}$ = 1.06 – 1.12, $z = 6.85$, $p < .001$] such that high-value words were better recalled than low-value words. Additionally, age significantly predicted recall [e^B = 5.26, $CI_{95\%}$ = 3.07 – 8.99, $z = 6.06$, $p < .001$] such that younger adults recalled more words from List n – 1 than older adults. However, value did not interact with age [e^B = 1.02, $CI_{95\%}$ = .98 – 1.07, $z = .95$, $p = .342$] such that younger and older adults were similarly selective when recalling words from List n – 1 (see Figure 5b).

Finally, we wanted to explore how an item’s previous retrieval impacts subsequent recall probability. First, we examined the probability of recall as a function of age and value after controlling for previous recall. Specifically, we examined memory for words on subsequent lists if they were recalled on Test n (see Figure 6a). For example, if the 10-point word had been recalled on Test 4, we examined the probability of recall for that word on Tests 5 and 6. A logistic MLM with item-level recall modeled as a function of value with age (young, old) as a between-subjects factor revealed that value significantly predicted recall [e^B = 1.02, $CI_{95\%}$ = 1.00 – 1.04, $z = 1.98$, $p = .047$] such that high-value words that were originally recalled were more likely to be recalled again than low-value words that were originally recalled. Additionally, age significantly predicted recall [e^B = 9.96, $CI_{95\%}$ = 4.73 – 20.99, $z = 6.04$, $p < .001$] such that, compared with older adults, younger adults were more likely to recall a word again if it was originally recalled. However, value did not interact with age [e^B = .99, $CI_{95\%}$ = .95 – 1.03, $z = -.59$, $p = .557$].

We were also interested in whether participants repeatedly recalled the same words as the task continued (e.g., recalling a word on Test 2, then again on Test 3). Thus, we examined the recall probability of words that were recalled on Test n – 1 (i.e., we examined the likelihood of recalling a word given it was recalled on the previous recall test; see Figure 6b). For example, if the 12-point word had been recalled on Test 2, we examined the probability of recalling that word again on Test 3. A logistic MLM with item-level recall modeled as a function of value with age (young, old) as a between-subjects factor revealed that value did not significantly predict recall [e^B = 1.01, $CI_{95\%}$ = .99 – 1.04, $z = 1.16$, $p = .247$]. However, age significantly predicted recall [e^B = 9.87, $CI_{95\%}$ = 4.53 – 21.51, $z = 5.76$, $p < .001$] such that, compared with older adults, younger adults were more likely to recall a word again if it was recalled on the previous test. However, value did not interact with age [e^B = .96, $CI_{95\%}$ = .91 – 1.01, $z = -1.75$, $p = .080$].

Discussion

In Experiment 2, to examine the role of interference from prior lists, we employed a novel paradigm whereby participants could recall words from prior lists to enhance their score in a value- directed remembering task. As illustrated in Figures 2 and 3, younger adults were more likely to recall words from previous lists than older adults, who recalled words mostly from the current list.

For example, on the final list, younger adults recalled more words from previous lists than the current list while older adults recalled more words from the current list than previous lists, demonstrating older adults' susceptibility to retroactive interference. Additionally, both younger and older adults recalled current-list words before previous-list words. Moreover, across all lists, including the recall of words from previous lists, younger adults were more selective for high-value words than older adults. This was likely driven by younger adults' enhanced selectivity when considering the recall of just words from the current list as selectivity did not differ between younger and older adults when examining recall for words recalled from List n – 1. This indicates that the enhanced selectivity observed in younger adults may be driven by the buildup of proactive interference in older adults in this context. Finally, value still had a small effect on recall once controlling for whether a word was recalled on its first test (but not when looking at recall from List n – 1), but this did not differ as a function of age. Thus, interference had a differential effect on younger and older adults, as older adults appeared to have very limited recall from earlier lists and instead focused their recall from the current list, whereas young adults could better engage memory for earlier information to enhance their score.

General Discussion

In everyday life, we are continuously presented with more information than we can remember and must selectively focus on the most important information with consequences for forgetting to maximize memory utility (e.g., Ariel et al., 2009; Castel et al., 2012; Madan, 2017; McGillivray & Castel, 2011; Murphy & Castel, 2020, 2021a, 2021b, 2022b; Murphy et al., 2022). However, most previous work examining how learners use value to guide memory processes has utilized procedures whereby participants are presented with a list of information to remember, are tested on that information, and then are presented with the next list of information followed by another test, with each test only examining memory for the just-studied list of information. Thus, it was previously unclear how interference, whether retroactive or proactive, impacts memory for valuable information when prior learning can influence task performance. Given that prior work has shown that older adults may experience deficits in overcoming interference (Hasher et al., 2002; Hay & Jacoby, 1999; Jacoby et al., 2010; Solesio-Jofre et al., 2012), we were interested in how interference could have the potential to differentially impact memory selectivity in younger and older adults.

In the current study, we presented participants with six lists of words paired with point values counting towards their score if recalled. Each list was followed by a free recall test for either the just-studied words (Experiment 1) or all words that had been studied to that point (Experiment 2). Results revealed that when tested on only the just-studied words, younger and older adults are similarly selective. However, when each recall test includes all studied words, younger adults frequently recalled words from previously studied lists to maximize their scores while older adults primarily recalled words from the just-studied list. This suggests that older adults may have suffered from retroactive interference whereby their memory for words they had recently studied impaired their ability to recall previously study words. Thus, interference plays an important role in the strategic encoding and retrieval of important information, especially in older adults.

Forgetting words from earlier lists, perhaps via a mechanism similar to that used for directed forgetting that is mostly intact in older age (Aslan & Bäuml, 2013; Titz & Verhaeghen, 2010), may have decreased proactive interference in Experiment 1, as words from earlier lists were not relevant in terms of the goals of the task. However, in Experiment 2, when participants could recall words from any studied list on each recall test (and thus recalling from a larger and larger pool of studied words as the task progressed), older adults demonstrated impaired selectivity for valuable information. Specifically, younger adults recalled more high-value words when considering just the recall of words from the current list, but younger and older adults were similarly selective in their recall of words from the list prior to the current list (e.g., the recall of List 4 words during the List 5 test). Thus, in Experiment 2, older adults' ability to selectively remember high-value words appears to have been impaired by the buildup of proactive interference (the previously learned words interfered with the recall of newly learned words), consistent with prior work demonstrating that younger adults are better able to recover from the effects of interference (cf., Andrés et al., 2004; Friedman & Castel, 2013; Lustig & Jantz, 2015).

After controlling for whether a word was recalled on its first retrieval test, value still had a small effect on memory such that high-value words that had been previously recalled were better remembered than low-value words that had been previously recalled (but this effect was not significant when considering the recall of words recalled from List n – 1). This suggests that the testing effect (i.e., testing or generating information benefits memory compared with restudying; see DeWinstanley & Bjork, 2004; Halamish & Bjork, 2011; Meyer & Logan, 2013; Roediger & Karpicke, 2006), which has been found in both younger and older adults, may produce a greater memory benefit for high-value relative to low-value information, although the present design does not balance opportunities to retrieve low- and high-value items (i.e., the high-value items, by virtue of getting more attention at study, will be more likely to be produced on each test). Future work could present learners with items differing in value and then provide a practice cued-recall test before a final test. Additionally, if there is an inherent value associated with certain words, this intrinsic value could influence younger and older adults' memory processes. For example, the word "health" may be more valuable to an older adult relative to a younger adult, and this could subsequently impact how information is prioritized in memory for health and medication information (see Hargis & Castel, 2018a; Whatley et al., 2021). Moreover, future research could examine memory in more systematic ways to determine the precise retroactive and/or proactive effects by testing associative memory (using paired associated learning and cued recall, see Jacoby et al., 2010) as opposed to using free recall which may encourage more strategic encoding and retrieval dynamics (e.g., Murphy & Castel, 2022a; Stefanidi et al., 2018) for high-value items.

In terms of older adults' reduced recall of previously studied information relative to younger adults (i.e., increased retroactive interference), some prior work suggests that older adults have less control over retrieval processes when there are multiple lists (Wahlheim & Huff, 2015). Thus, it may be that older adults can focus on recalling the current list, perhaps due to the optimization of short-term memory coupled with impairments in the accessibility of earlier lists. In contrast, younger adults may be able to benefit from gaining points from words on prior lists as well as the current list and engage in regulatory focus that promotes gains and balances losses on the current list (younger adults were more selective when examining just the recall of words from List n in Experiment 2). It would be interesting to determine if older adults could recall earlier words if incentivized. For example, if words from earlier lists were worth double their initial point value, older adults may be more able to overcome interference, but this sort of incentive could come at the expense of current list items (as older adults would need to change their strategy and prioritize items from earlier lists).

In a related domain, one theoretical explanation for older adults' lack of recall of words from prior lists could be based on time-perspective and socioemotional selectivity theory (Charles & Carstensen, 2010; see also Baltes et al., 2014) which suggest that younger and older adults view time in different ways and that older adults are more "present-focused" (for a summary, see Fung & Isaacowitz, 2016). In the current paradigm, older adults may need to focus on the current list, as opposed to trying to gain points from prior lists, due to the rapid forgetting and loss of access to earlier list information, and this might be a compensatory strategy. As such, older adults may choose to focus on the current list to minimize losses that could result in trying to remember earlier lists and forgetting information that was just presented in the current list. However, age-related differences in executive function and inhibitory control may play a large role in the present task since older adults may have stronger access to current learning as well as faster forgetting of the earlier information, and also may not be able to inhibit recall of current information to access prior list items (cf., Lustig et al., 2007).

While the present study demonstrated that younger adults may be more able to overcome interference to remember important information, future work could examine the strategies younger and older adults use to forget previous low-value words and remember the high-value words from each list (e.g., Hennessee et al., 2019). Specifically, younger and older adults may have engaged in different encoding and/or retrieval strategies leading to their differential recall of current- and prior-list items. For example, it is unclear what strategies younger adults used to prioritize high-value items when recalling words from the just-studied list. There may be important age-related differences in the strategies used to encode and recall high-value items when faced with interference.

In terms of the accessibility of the words, some work suggests that older adults encode and maintain access to distractors (e.g., words superimposed on pictures), but not at a cost to memory for target information (see Weeks & Hasher, 2017). Here, both younger and older adults could have retained access to both low- and high-value words, but low-value words may be more susceptible to interference. Particularly, it is likely that words not recalled from the current or prior lists are not necessarily "gone and forgotten" but that participants use some form of cognitive control to enhance the recall of higher-valued words while suppressing the recall of lower-valued words. Some evidence for this may come from prior work on value-directed remembering where some words are paired with negative points values (thus there is a penalty for recalling them; see Castel et al., 2007). In this type of paradigm, both younger and older adults did not recall negatively valued words during the recall task following each list, but on a final surprise recognition test where participants were asked to identify all words (both positive and negative value) that had been presented on the lists, older adults were more likely than younger adults to recognize the negatively valued words. This suggests that the non-recalled words are not forgotten, and perhaps some form of impaired inhibitory control leads to older adults encoding these words. In the present task, it may be that older adults still have access to non-recalled words, suggesting that these words are not forgotten, but were not accessible via recall mechanisms. Future work using priming or a surprise recognition test could shed more light on whether earlier items are still accessible but not recallable, especially in older adults.

While we focused on retroactive interference in terms of total recall, there likely is also proactive interference that contributes to impairments in the learning of future lists. The current paradigm was not designed to directly measure or rule out the role of proactive interference, as this form of interference could enhance the recall of items from prior lists, such that older adults might benefit from impairments in this context. Future research that controls for or measures proactive interference using semantically related information in early lists, and then a release of proactive interference by switching to new material, could be informative. Additionally, future research could include separate measures of recall for each prior list that is not impacted by the current list, or a source recall test to determine if repeated testing impacts memory for its source (Henkel, 2007). Furthermore, it would be interesting to examine metacognitive aspects, as older adults may become aware that they are recalling items mostly from the current list, especially if this is an adopted strategy to maximize scores on later lists.

We would like to note that the demographic composition of our younger and older adult samples may be a potential limitation of the present work (see Dupree & Kraus, 2022 for a discussion of the potential impacts of demographic information on psychological science; see also Greene & Naveh-Benjamin, 2022 for how online sampling of older adults may influence research findings); future research could examine the effects of interference in value-based memory in other populations and using different sampling procedures. Additionally, although more older adults admitted to cheating (e.g., writing down words to prevent forgetting) in a post-task questionnaire and were excluded, particularly in Experiment 2, it is possible that older adults did not cheat more than younger adults; rather, they may have been more forthcoming about their cheating (as previous work suggests that older adults tend to be more honest than young adults; see O'Connor et al., 2021). Future work may also benefit from replicating the present effects in the lab and with materials that have everyday significance, vary in terms of relevance or importance, and have similarity-based interference/require updating, as this could have implications for remembering past and current information about medication and side effects (Hargis & Castel, 2018b), and financial information, which could influence susceptibility to scams and fraud.

In sum, the present study revealed that when presented with more information than one can remember, younger adults were less susceptible to retroactive interference and overall, were more likely to recall valuable information. Therefore, although selectivity is preserved in older adults when study-test cycles are independent, the proactive interference from previously studied words reduced selectivity in older adults. Specifically, while older adults may focus more on the current list, possibly by relying on short-term memory and being "present-focused" (Weiss et al., 2016), younger adults were more selective in their recall of just-presented words while also recalling more words from prior lists. Thus, younger adults can better access and benefit from recently studied high-value words as well as information from earlier lists. As such, younger adults may benefit from greater control over proactive and retroactive interference to engage in value-directed remembering while older adults may experience impairments in the strategic control over inference from prior lists and are more prone (or only able) to focus on the current list material to maximize memory performance. There may be differences in time perspective contributing to some older adults being more "present-focused" which could result in recalling words from the current list, and not prioritizing words from earlier words which could interfere with recall, and result in loss of access to the current list, although future research should test this notion in more detail and examine potential individual differences in relevant executive control mechanisms that contribute to overcoming the effects of interference.

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Public Significance Statement

When presented with more information than one can remember, younger adults are better at combating interference and recalling valuable information, while older adults may engage in selective forgetting of previously learned information to enhance a "present-focused" form of memory.

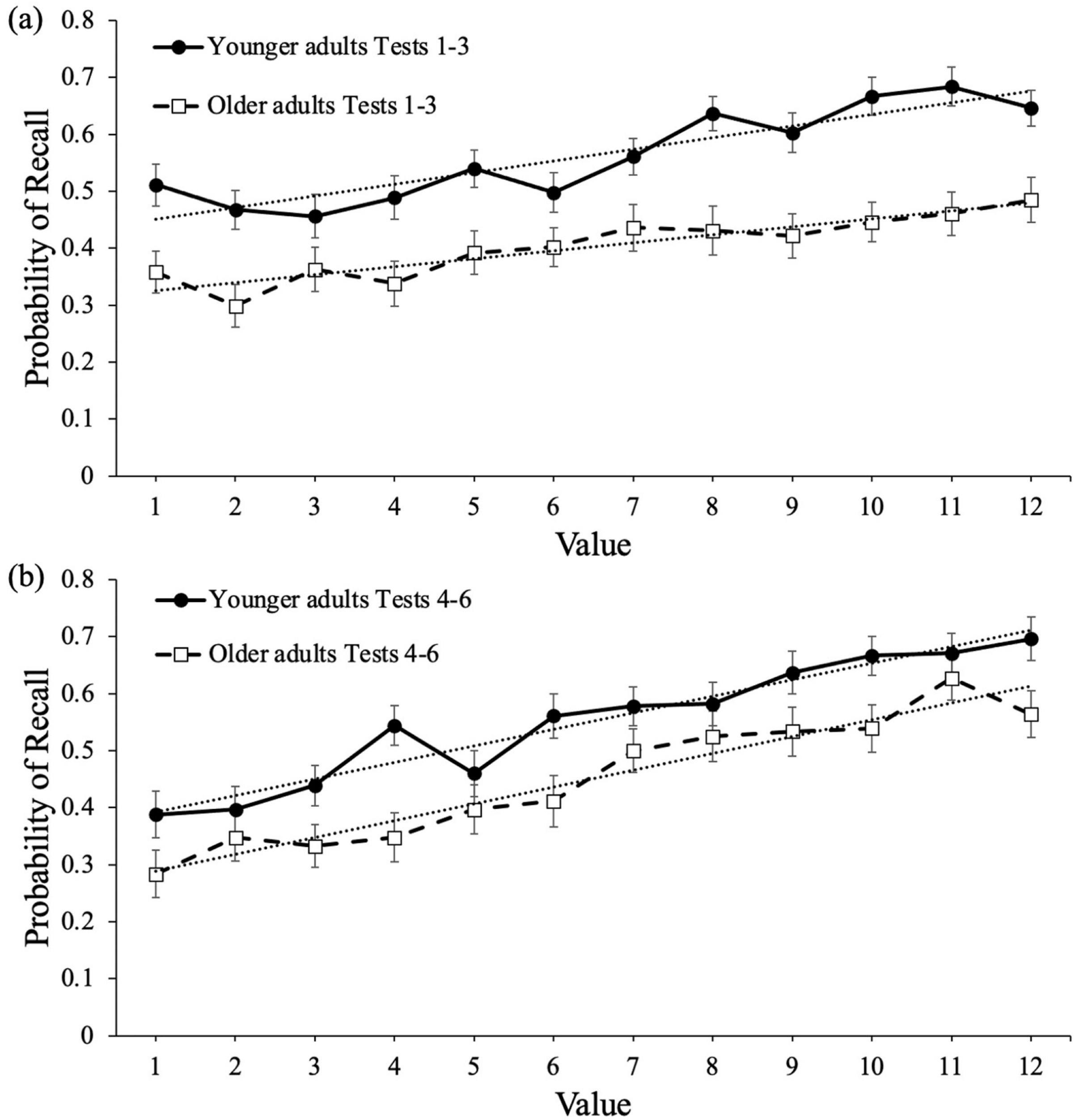

Figure 1.

Probability of recall as a function of age and word value with linear trendlines on Tests 1-3 (a) and Lists 4-6 (b) in Experiment 1. Error bars reflect the standard error of the mean.

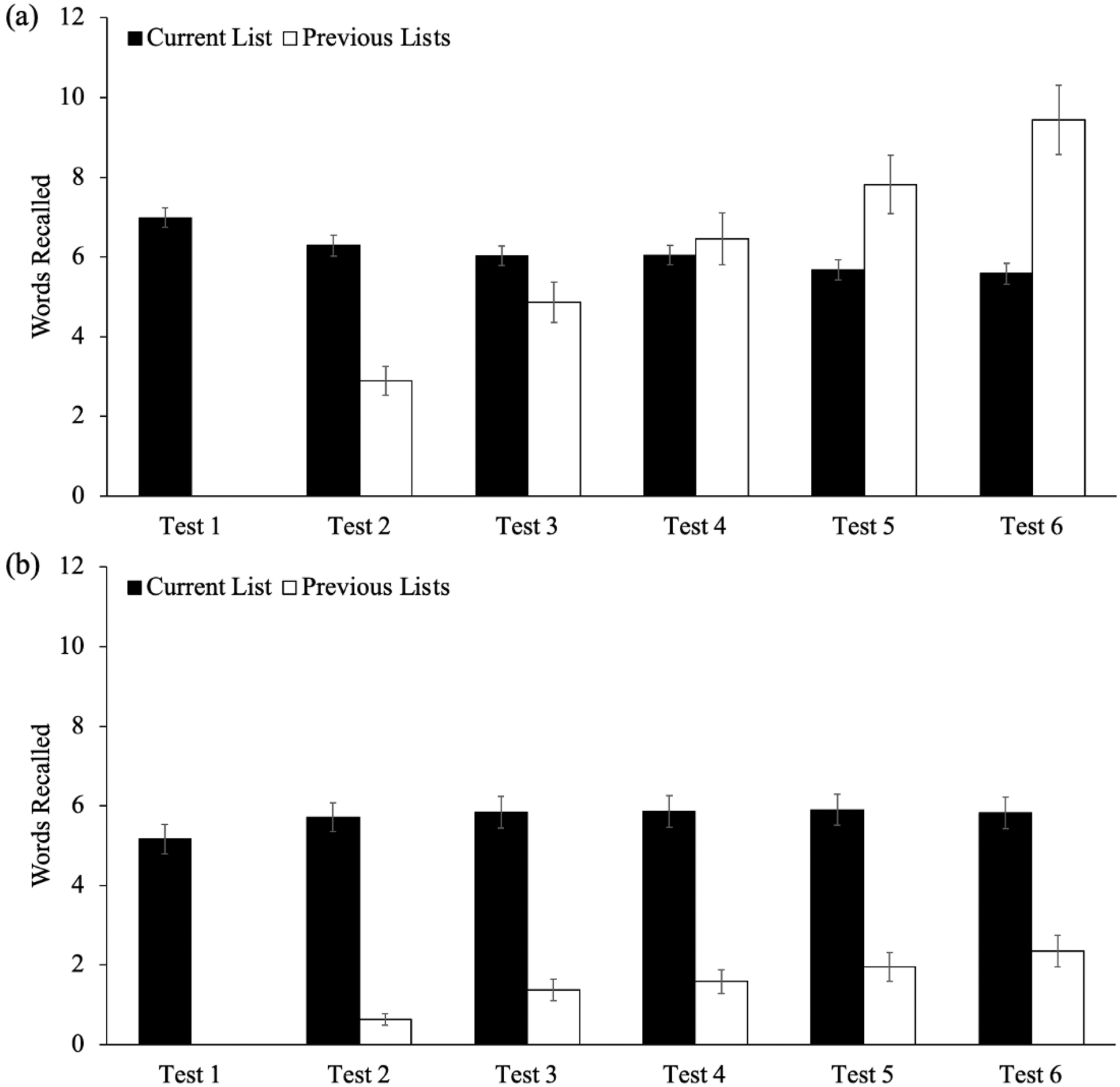

Figure 2.

The number of words recalled as a function of test number and list source for (a) younger adults and (b) older adults in Experiment 2. Error bars reflect the standard error of the mean.

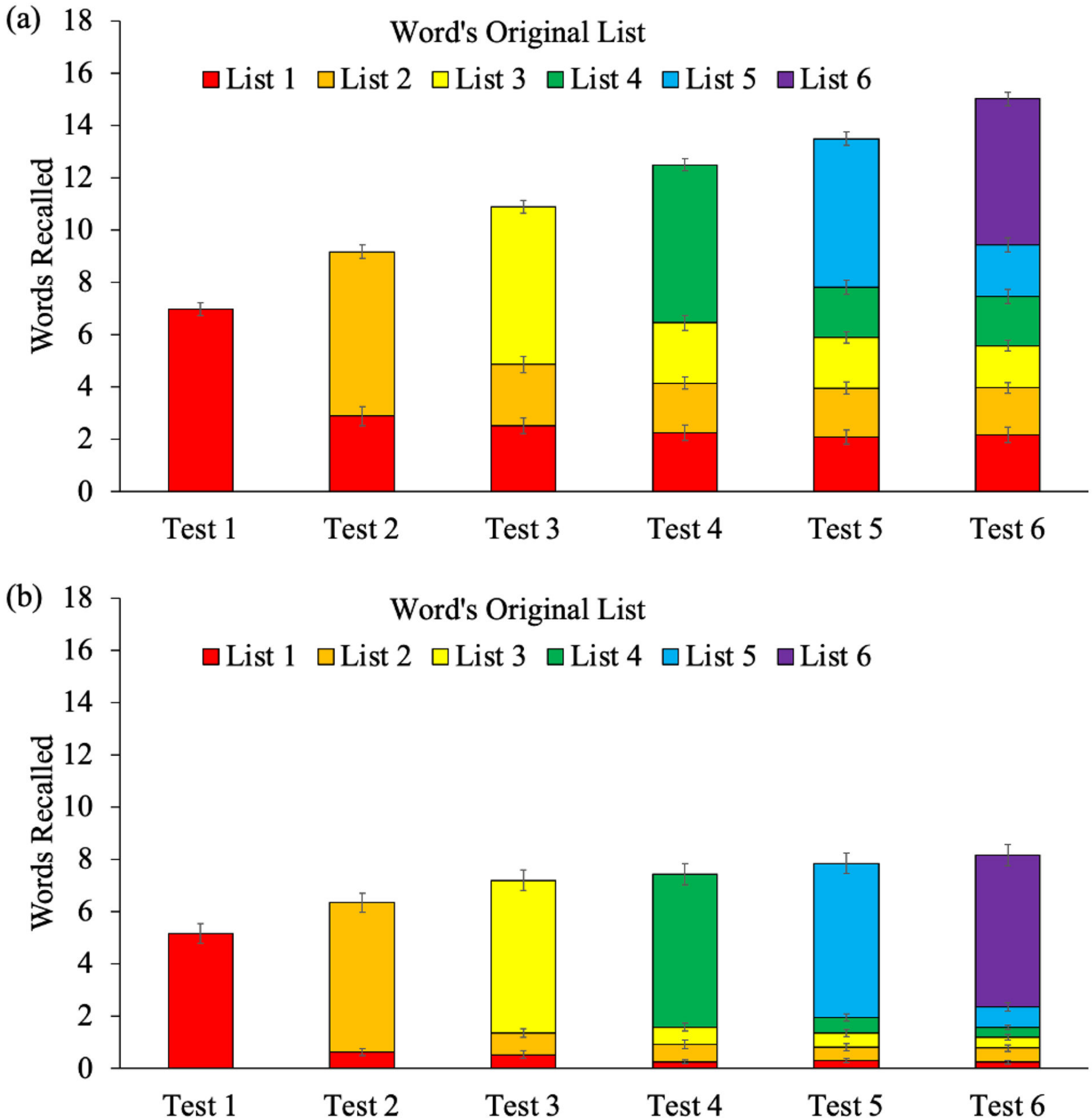

Figure 3.

The number of words recalled on each test as a function of the original list it was presented on for (a) younger adults and (b) older adults in Experiment 2. Error bars reflect the standard error of the mean.

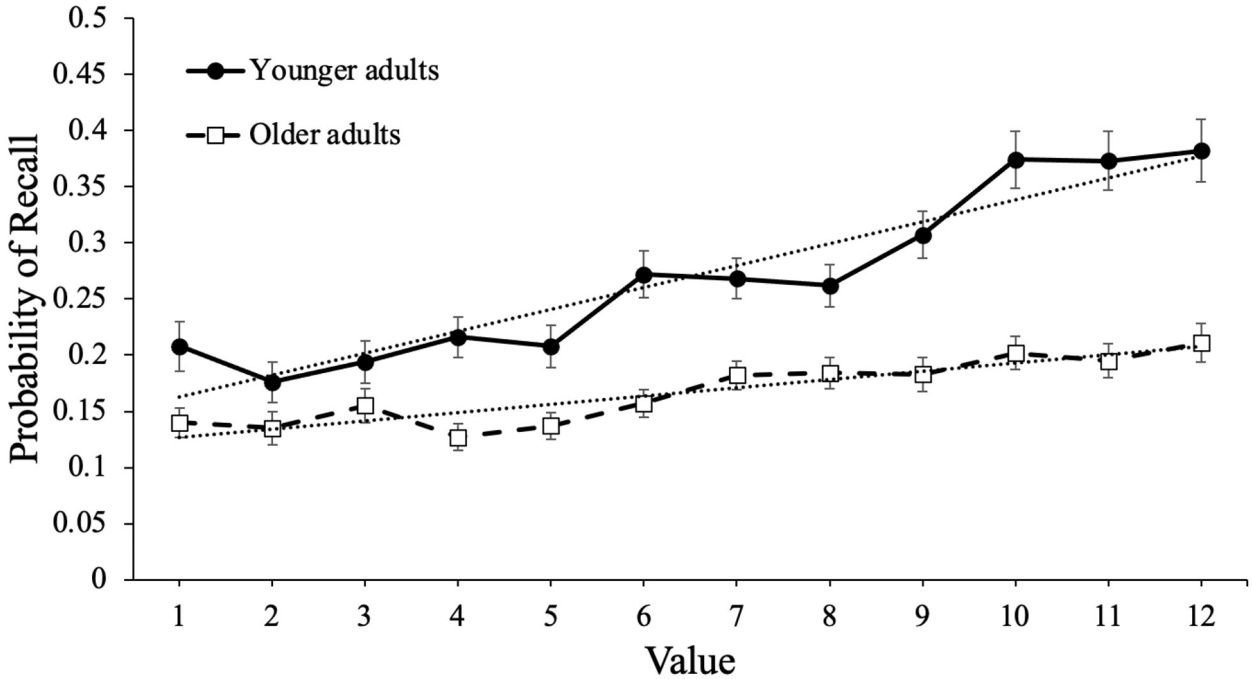

Figure 4.

Probability of recall as a function of age and word value with linear trendlines across all recall tests in Experiment 2. Error bars reflect the standard error of the mean.

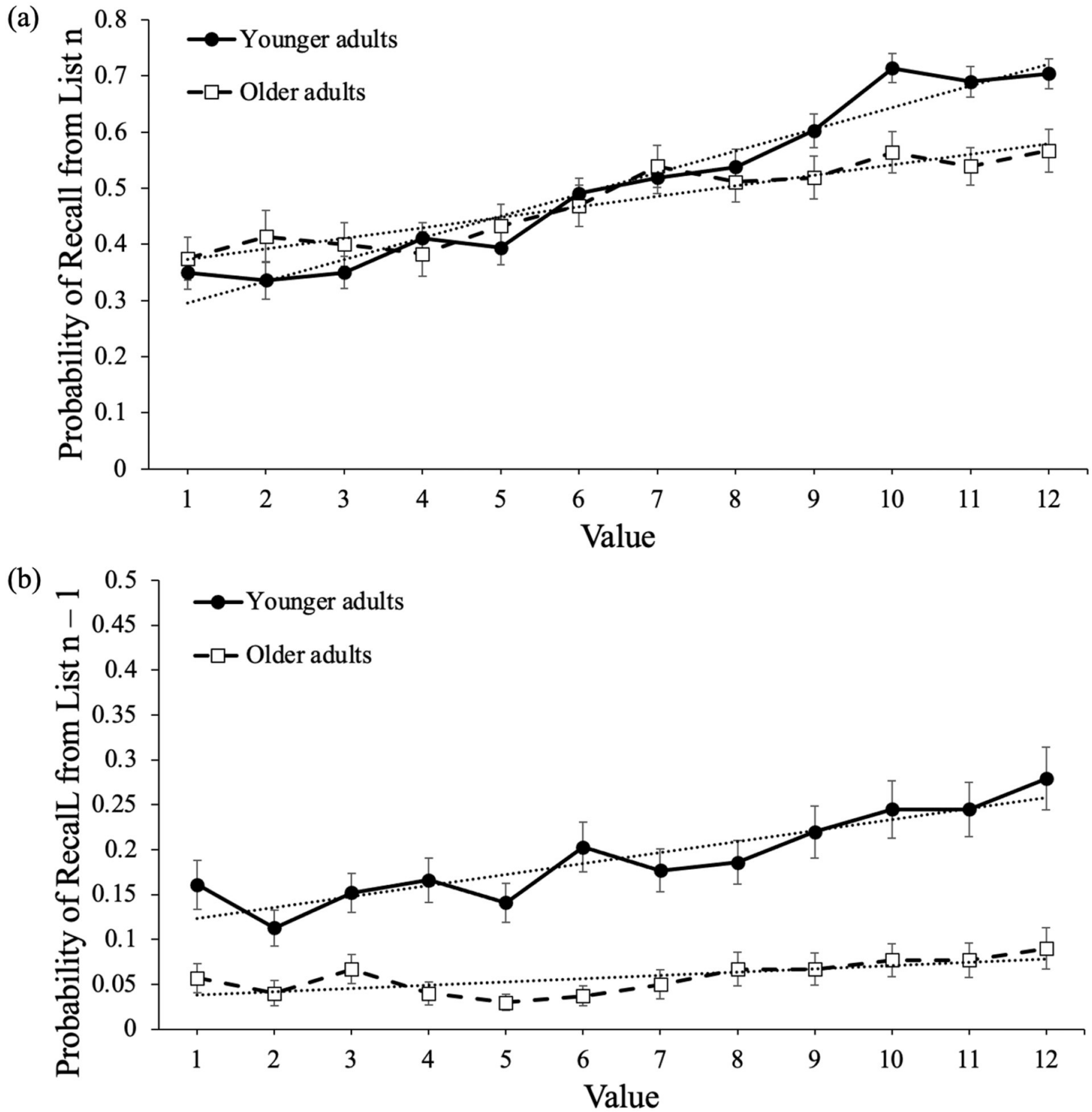

Figure 5.
Probability of recall as a function of age and word value with linear trendlines for words from List n (a) and List n – 1 (b) in Experiment 2. Error bars reflect the standard error of the mean.

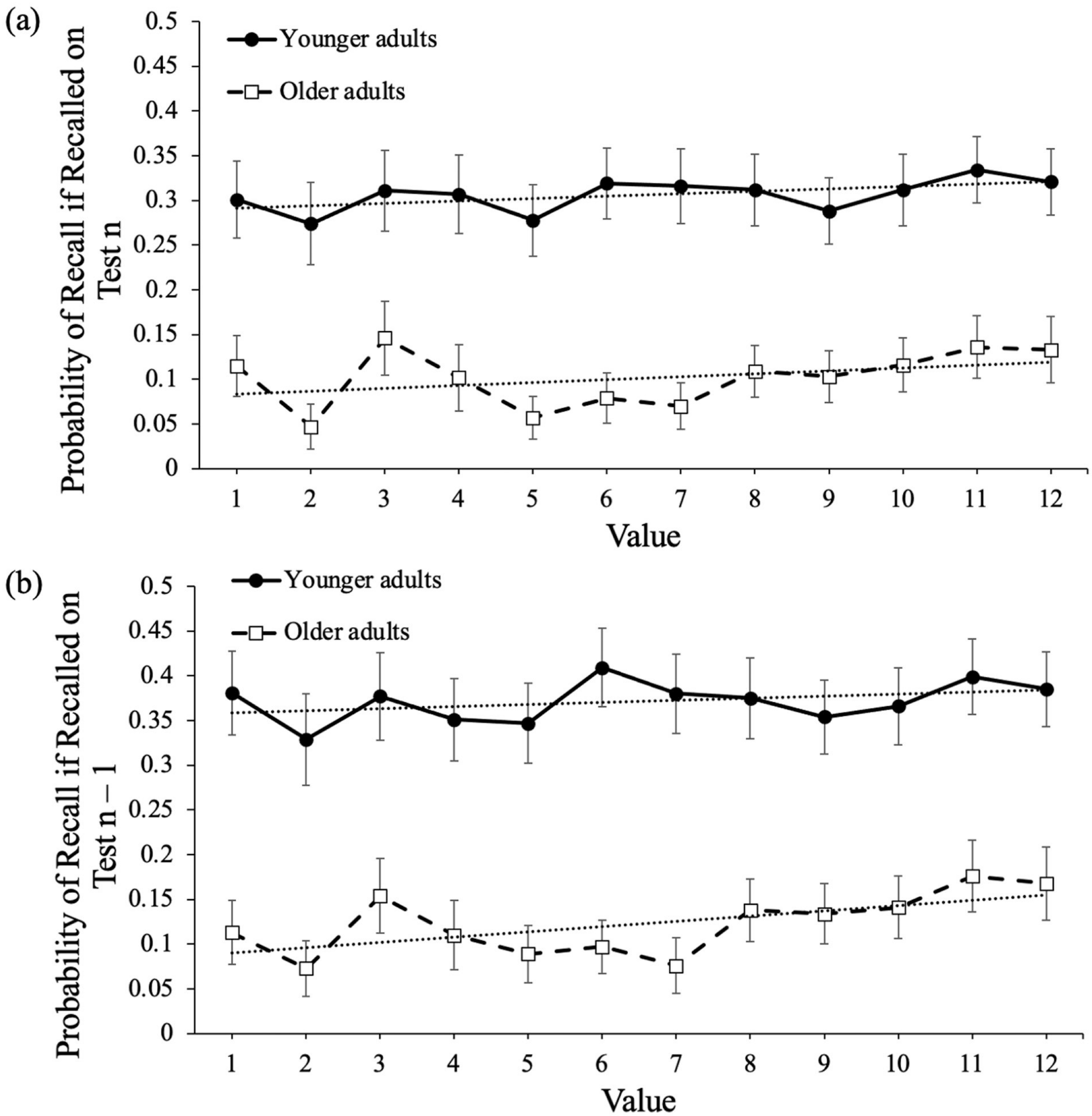

Figure 6.

Probability of recall as a function of age and word value with linear trendlines after controlling for recall on Test n (a) and probability of recall as a function of age and word value with linear trendlines if recalled on Test n – 1 in Experiment 2. Error bars reflect the standard error of the mean.