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Age-related Associative Memory Deficits in Value-based Remembering: The Contribution of Agenda-based Regulation and Strategy Use

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Abstract

Value-based remembering in free recall tasks may be spared from the typical age-related cognitive decline observed for episodic memory. However, it is unclear whether value-based remembering for associative information is also spared from age-related cognitive decline. The current experiments evaluated the contribution of agenda-based based regulation and strategy use during study to age differences and similarities in value-based remembering of associative information. Participants studied word pairs (Experiments 1-2) or single words (Experiment 2) slated with different point values by moving a mouse controlled cursor to different spatial locations to reveal either items for study or the point value associated with remembering each item. Some participants also provided strategy reports for each item. Younger and older adults allocated greater time to studying high than low valued information, reported using normatively effective encoding strategies to learn high-valued pairs, and avoided study of low-valued pairs. As a consequence, both age groups selectively remembered more high than low-valued items. Despite nearly identical regulatory behavior, an associative memory deficit for older adults was present for high valued pairs. Age differences in value-based remembering did not occur when the materials were word lists. Fluid intelligence also moderated the effectiveness of older adults' strategy use for high valued pairs (Experiment 2). These results suggest that age differences in associative value-based remembering may be due to some older adults' gleaning less benefit from using normatively effective encoding strategies rather than age differences in metacognitive self-regulation per se.

Keywords

Metacognition; self-regulated learning; aging; agenda-based regulation; value-based remembering

Remembering important information is crucial for achieving daily goals such as picking up items at a grocery store or studying material for an upcoming exam. Value-based remembering requires individuals to comprehend item value and adjust their study behavior to emphasize memory for high-value information (Castel, 2008). The agenda-based regulation framework of study-time allocation proposes that this involves construction of a

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goal-oriented agenda or plan that serves as the learner's decision criterion for allocating time, resources, and effort to encoding information (Ariel, Dunlosky, & Bailey 2009; Dunlosky & Ariel, 2011). Learners' agendas aim to maximize performance by prioritizing valuable information over less valuable information.

For older adults, prioritizing valuable information may be especially important because aging is characterized by declines in episodic memory processes (Craik & Jennings; 1992; Kausler, 1994; Light, 1991; Rönnlund et al., 2005), which may require older adults to be more selective about what they attempt to learn (Price & Murray, 2012). In particular, learning new associations is impaired in later adulthood (e.g., Chalfonte & Johnson, 1996; Dunlosky, Hertzog, & Powell-Moman, 2005; Old & Naveh-Benjamin, 2008). The goal of the current experiments was to evaluate whether there are age differences in value-based remembering for associative information and in the self-regulated study strategies that support value-based remembering.

Evidence suggests that older adults may be quite good at remembering valuable information in free recall tasks. Specifically, older adults show equivalent recall of high-value words despite overall age differences in number of words recalled (Castel, 2008; Castel, Benjamin, Craik, & Watkins, 2002; Castel, Farb, & Craik, 2007; Castel, Humphreys, Lee, Galvan, Balota, & McCabe, 2011; McGillivray & Castel, 2011). Older adults show greater selectivity for remembering high value words, in part because they may utilize regulatory strategies to compensate for their memory deficits. For instance, older adults selectively restudy high valued words immediately before recall to take advantage of recency effects in free recall (Castel et al., 2013).

Is value-based remembering for associative information also spared from age-related cognitive decline? Price, Hertzog, and Dunlosky (2010) found age differences in memory for high-value information for Spanish vocabulary learning. However, their age differences could be due to use of materials that were heterogeneous in difficulty; many of which were too difficult to learn even for younger adults (see Dunlosky & Ariel, 2011; Metcalfe, 2002). Such conditions may have encouraged avoidance of difficult items regardless of value, if individuals believed they could not possibly learn all items in a single pass during study. Consistent with this hypothesis, Price et al. (2010) found that older adults with low memory self-efficacy avoided studying high-difficulty items.

There are several reasons to suspect that older adults' value-based remembering would not be impaired for associative information. First, metacognitive monitoring processes that drive self-regulated study decisions appear to be largely spared by aging (for a review, see Hertzog, in press). Second, older adults' beliefs about age-related memory limitations could lead to use of compensatory regulatory strategies to ensure important associative information is encoded (e.g., Dixon & deFrias, 2007), including selective utilization of effective encoding strategies when studying high valued items. When older adults (1) use effective mediational strategies during encoding (e.g., interactive imagery, sentence generation) that are known to benefit associative recall (Paivio, 2006; Richardson, 1998) and then (2) explicitly search for those mediators at retrieval, their deficit in associative recognition memory is attenuated if not eliminated (Naveh-Benjamin, Brav, & Levy, 2007).

Experimental manipulation of item value may promote spontaneous use of effective encoding strategies for high-value items that eliminate associative memory differences for valuable information.

Value may promote strategy use in young adults. Learners' pupil dilation (a reflection of changes in processing demands; Beatty, 1982) is greater during study of high than low valued information (e.g., Ariel & Castel, 2014; Bijleveld, Custers, & Aarts, 2009), suggesting greater effort allocation (and perhaps use of cognitively demanding strategies) during encoding of high-value items. Festini, Hartley, Tauber, and Rhodes (2013) found that value-related benefits on memory for face–name associations were eliminated by forcing learners to use a relatively ineffective rote repetition study strategy. However, to date no experiment manipulating value has explicitly measured strategy use.

Overview of the Current Experiments

The current experiments evaluated younger and older adults' value-based remembering and self-regulated study strategies during paired-associate learning. The experiments used a mouse tracing paradigm (Norman & Schulte-Mecklenbeck, 2010) to separate value-seeking behavior from actual study. On each trial, participants could move a mouse-controlled cursor to a value-grid location, revealing the point value of the item pair in the corresponding location or to a corresponding grid containing the items themselves (see Figure 1). This procedure allowed us to track the decision process dynamically and determine if people would search for value if that process was under their own control.

The amount of dwell-time on a given location was also recorded to measure the time allocated to studying. In addition to study-time allocation, we also evaluated how younger and older adults used their study time by eliciting either concurrent (Experiment 1b) or retrospective (Experiment 2) self-reports of strategy use. This allowed us to evaluate the hypothesis that value motivates the selective use of high-quality strategic encoding operations.

Strategy reports were obtained immediately after each study trial in Experiment 1b. Strategy reports were not obtained in Experiment 1a to ensure that any potential age differences in study time allocation and value-based remembering observed were not due to participants altering their regulatory strategies in response to strategy report options. In Experiment 2, retrospective strategy reports were obtained after all study and testing had occurred which allowed us to measure time use again without concerns of reactive effects of strategy reports. Experiment 2 also directly compared the associative task from Experiment 1 with a task adapting the free-recall approach used by Castel and colleagues, allowing us to probe analytically task-type effects on age differences in value-based remembering.

For each experiment, if study-time allocation decisions are influenced by a value-based agenda, then both younger and older adults should seek out and use knowledge about the location of valuable formation to guide their study choices. If value-based remembering is spared from age-related cognitive decline then younger and older adults should display equivalent memory for high valued information. However, if the associative memory deficit persists despite value-directed adjustments in study behavior, then age groups should differ in memory for high valued items.

Experiment 1a

Method

Participants—Experiment 1a was conducted concurrently with Experiment 1b and participants were randomly assigned to each experiment. Twenty older adults (10 females, 10 males, *M* Age = 70 years old, range 60-79) and twenty younger adults (8 females, 12 males, *M* Age = 19 years old; range 18-25) completed Experiment 1a. Older adults were recruited from the Atlanta metropolitan area. Younger adults were psychology students from Georgia Tech (*N* = 11) and the University of Alabama in Huntsville (*N* = 9). All older adults had at least a high school diploma, with 85% holding at least a Bachelor's degree and 55% some kind of post-baccalaureate training. All older adults had self-reported good health and computer experience. In all experiments reported here, older adults received $10 per hour and compensation for travel expenses; younger adults received course credit for participation.

Materials—One hundred twenty concrete noun-noun paired associates (e.g., *icebox* – *elephant*) were randomly assigned to experimental trials and grid locations. Items were randomly assigned unique point values of 2, 4, 6, 8, 10, or 12 on each trial.

Procedure—Participants were instructed they would be learning paired associates for a cued-recall test. They were also instructed that each pair's point value indicates how important it is to remember. On each trial, participants could study up to 6 pairs and view the point value of them by moving the mouse-cursor to cells of a 3×2 array labeled *study item* or a 3×2 array labeled *item value*. A typical trial is illustrated in Figure 1. The *study item* array was always presented on the left spatially and the *item value* array was always presented on the right. English readers habitually scan information in a left-to-right fashion (Ariel et al., 2011). We deliberately placed the value array on the right to ensure that initial value selections were not merely due to habitual reading patterns.

To adjust for age-related slowing for perceptual, cognitive, and motor processes (Birren, 1970; Salthouse, 1996), older adults were given 50 s to study on each trial, whereas younger adults were given a maximum of 25 s (see Price et al., 2010). We chose a ratio of 2:1 because older adults typically take between 1.6-1.8 times longer than younger adults to make complex decisions (Verhaeghen, 2013).

Before beginning, participants were shown how to find a pair that was a specific value (e.g., find the pair worth 4 points) and how to find the value associated with a specific pair. Point values and pairs were arranged so that location A1 of the study pair array corresponded to A1 of the point value array, B1 with B1, and so on. The order participants were trained to find value vs. pairs was counterbalanced to ensure that it did not bias their search order. Counterbalancing did not influence choice behavior.

During instructions, participants were informed that their goal was to earn as many points as possible. Before beginning trial 1, they were asked to report this goal explicitly and were reminded of it before the first trial. On each trial of the study phase, the word pair array, value array, and timer depicted in Figure 1 were presented. The timer began at 25 seconds for younger adults and 50 seconds for older adults and decreased 1 every second until reaching 0. Participants were free to allocate time to word pairs or their value by moving the mouse cursor into each corresponding cell. The information in the cell selected would remain visible until the mouse cursor was moved outside of it. The mouse cursor was always located in the top-left corner of the computer screen at the start of each trial so that selections would not be biased by the mouse position at the end of each trial.

After studying 10 grids, participants were serially tested for associative cued-recall for the 60 word pairs in a random order. The first word of each pair was presented and participants were prompted to type the second word. After this test, participants were told the number of items they recalled and their total points earned. They were then encouraged to try to earn more points in the next round. The experiment then continued with a second study-test block using 60 new pairs.

Results & Discussion

All analyses, unless noted otherwise below, involved 2 (Age: young vs. old) × 2 (Block: 1 vs. 2) × 6 (Value: 2, 4, 6, 8, 10, or 12) repeated measures ANOVAs with Block and Value as within-subjects factors.

Study-time Allocation—Value selection, reflecting choices to consider value during study, was computed as the number of times the mouse cursor entered a value cell. On average people accessed each value cell once to identify how valuable items were for study (2 point: *M* =1.10, *SE* =.11; 4 point: *M* =1.10, *SE* = .11; 6 point: *M* =1.10, *SE* = .11; 8 points: *M* =1.19, *SE* = .13; 10 points: *M* =1.47, *SE* = .12; 12 points: *M* =1.41, *SE* = .12). They were also more likely to review cells containing higher values, $f(5,34) = 9.83$, $MSE = 2.81$, $p < .001$, $\eta_p^2 = .21$, probably as a verification check of memory for the identity of high value items. Because both these findings were consistent across all experiments, we do not discuss value selection in subsequent experiments.

The proportion of trials in each block in which the value array was selected first overall was computed to assess the time course of value discovery during study for younger and older adults (Table 1). There were no age differences in preference for selecting value first overall, $f(1,38) = 1.68$, $MSE = .30$, $p = .20$, $\eta_p^2 = .04$. However, preference for selecting value first increased across blocks, $f(1,38) = 8.19$, $MSE = .53$, $p < .01$, $\eta_p^2 = .18$. The interaction was not significant, $F < 1$. The relatively low rates of initial value discovery likely reflects the effects of reading habits biasing initial study choices toward information presented leftward spatially (Ariel et al, 2011; Ariel & Dunlosky, 2013).

Next, consider item selection (study/restudy decisions), computed as the frequency in which the mouse cursor entered word pair cells as a function of point value (Table 2). Item selection increased as item value increased, $f(5,34) = 42.08$, $MSE = 57.19$, $p < .001$, $\eta_p^2 = .53$, and the amount of restudy decreased from block 1 to block 2, $f(1,38) = 13.94$, $MSE =$

136.36, $p < .001$, $\eta_p^2 = .27$. Age did not influence item selection, $f(5,34) = 2.71$, MSE = 59.67, $p = .11$, $\eta_p^2 = .07$, and no 2-way interactions were significant, $Fs < 1.59$. However, the 3-way interaction was significant, $f(5,34) = 2.43$, $MSE = 2.87$, $p < .05$, $\eta_p^2 = .06$. The Age x Value interaction was significant for block 1, $f(5,34) = 4.34$, MSE = 4,62, $p < .01$, $\eta_p^2 = .10$, but not for block 2, $F < 1$. Younger adults were less likely to study low point items (2-6 points) during block 1 than older adults, $ts > 2.22$.

The proportion of total time allocated to studying pairs was computed by summing the dwell time in the word pair cells and dividing by the total time available for study on each trial (25 or 50 sec). Effects for age, $f(1,38) = 17.06$, $MSE = .34$, $p < .001$, $\eta_p^2 = .31$, and value were significant, $f(5,34) = 29.86$, $MSE = .55$, $p < .001$, $\eta_p^2 = .44$. These main effects were qualified by an Age x Value interaction, $f(5,34) = 3.62$, $MSE = .07$, $p < .05$, $\eta_p^2 = .09$, generated by younger adults allocating proportionally more time to learning 12-point words than older adults, $t(38) = 3.62$, $p < .01$. A Block x Value interaction, $f(5,34) = 3.03$, $MSE = .04$, $p < .05$, $\eta_p^2 = .07$, indicated that study-time allocation increased for 12-point items across blocks, $t(38) = 2.90$, $p < .05$, but no other effects were significant, $F < 2.20$.

Overall the patterns for time allocation presented in Figure 2 were very similar for younger and older adults, with the major difference being that younger adults allocated a greater portion of their total time to studying 12-point items. Note, however, that older adults were given more time to select and study material on each trial than younger adults to compensate for their slower mouse movements and processing speed. Thus, even though the proportion of total time was higher for younger adults than older adults, the actual time allocated (in milliseconds) to items was equal for older (M = 9621, SE = 1150) and younger adults (M = 8657, SE = 983), $t < 1$. Most important, the similar time allocation patterns in Figure 2 support our conclusion that the processes that influence the implementation of a value-based agenda during study-time allocation appear to be spared with aging.

Recall Performance—Table 3 presents the mean proportion of correctly recalled pairs for each value level across blocks. Effects for age, $f(1,38) = 6.33$, $MSE = 1.80$, $p < .05$, $\eta_p^2 = .14$, block, $f(1,38) = 23.58$, $MSE = 48$, $p < .001$, $\eta_p^2 = .38$, and value, $f(5,34) = 35.11$, MSE = 1.45, $p < .001$, $\eta_p^2 = .48$, were all significant. These main effects were qualified by a significant Value x Age interaction, $f(5,34) = 2.47$, $MSE = .10$, $p < .05$, $\eta_p^2 = .06$, which revealed that younger adults recalled more of the highest valued items (8-point: $M = .30$, $SE = .06$; 10-point: $M = .37$, $SE = .06$, and 12-point: $M = .52$, $SE = .04$) than did older adults (8-point: $M = .13$, $SE = .05$; 10-point: $M = .20$, $SE = .06$, and 12-point: $M = .31$, $SE = .07$), $ts(38) > 2.10$. The groups did not differ in memory for low valued items (2-point: $M = .09$, $SE = .02$; 4-point: $M = .09$, $SE = .02$, and 6 points: $M = .09$, $SE = .02$), $ts(38) < 1$. Thus, younger adults were more effective than older adults at recalling high-value information. An Age x Block interaction was also significant, $f(1,38) = 8.64$, $MSE = .18$, $p < .01$, $\eta_p^2 = .19$, because younger adults remembered more word pairs on Block 2 than older adults (Younger: $M = .31$, $SE = .04$; Older: $M = .15$, $SE = .04$), $ts(38) = 2.89$, $p < .01$, but the age groups did not differ in Block 1 performance (Younger: $M = .21$, $SE = .03$; Older: $M = .12$, $SE = .03$), $t(38) = 1.89$, $p = .07$. The three-way interaction was not significant, $f(5,34)$ = 2.04, $MSE = .03$, $p = .076$, $\eta_p^2 = .05$.

To summarize, younger and older adults both selectively remembered high valued information at the expense of less valuable information. Even so, an associative memory deficit for valuable information was present with older adults displaying much poorer memory for the highest valued information despite relative age equivalence for low valued information.

Experiment 1b

In Experiment 1a, age groups allocated their study time in a qualitatively similar fashion, but age differences in remembering occurred for high valued associative information. Perhaps older adults used their time to implement less effective encoding strategies on high valued information. In Experiment 1b, we prompted participants to provide strategy reports following each trial. These types of concurrent strategy reports are relatively accurate (Dunlosky & Hertzog, 2001) and enabled evaluation of whether value motivates the use of effective encoding strategies. If so, then participants should more often report using more normatively effective encoding strategies (e.g., mediational strategies like interactive imagery; Richardson, 1998) for high value items. If differential strategy use produces age differences in value-based remembering, then younger adults should report more frequent use of effective strategies for those items than older adults.

Method

Participants—Twenty older adults (15 females, 5 males, *M* Age = 69 years old, age range 60-79) from the Atlanta metropolitan area and seventeen younger adults (5 females, 12 males, *M* Age = 20 years old, age range 18-23) from Georgia Tech (*N* = 9) and the University of Alabama in Huntsville (*N* = 8) completed this experiment. All older adults had at least a high school diploma. The majority of older adults were college educated (Technical/Trade degree = 25%; Bachelor's degree = 60%; graduate degree = 20%), had self-reported good health, and computer proficiency.

Materials & Procedure—Materials and procedure were identical to Experiment 1a with the exception that participants made strategy reports following each trial. To make strategy reports, each grid location for that study trial was represented in an enlarged format. The cue word of the pair was presented inside of this location. Participants selected the strategy (or strategies) they used to study the highlighted pair by checking a box next to each strategy they remembered using. They selected from the following closed response options: (1) I did not study this pair, (2) I do not remember my strategy or strategies, (3) I repeated both words to myself, (4) I visualized an image using both words, (5) I thought of how the two words were related, (6) I generated an idea to link both words, (7) I generated a sentence using both words, or (8) Other. If participants selected the “Other” option, they were also instructed to type the strategy they used into a textbox. The instructions emphasized participants should only report strategies that they were confident they used during study. Participants made strategy reports beginning with the pair located in cell A1, then moving clockwise.

Results

Study-time Allocation—The proportion of trials in each block that participants selected the value array first is presented in Table 1. Once again, early value discovery increased across blocks, $f(1,35) = 10.07$, $MSE = .47$, $p < .01$, $\eta_p^2 = .22$. Effects for age and the interaction effect were not significant, *Fs* < 1.75.

Mean item selection for each value level is presented in Table 2 as a function of age and block. Participants' frequency of study of word pairs increased as point value increased, $f(5,31) = 4.59$, $MSE = .75$, $p < .001$, $\eta_p^2 = .12$. Total item selections also decreased across blocks, $f(1,35) = 2.41$, $MSE = 10.87$, $p < .13$, $\eta_p^2 = .06$, but did not differ across age groups, $F < 1.01$. No interactions were significant, *Fs* < 1.5.

Figure 2 presents the proportion of time allocated to studying items as a function of value. People allocated more time to studying high than low valued pairs, $f(1,35) = 10.82$, $MSE = .10$, $p < .001$, $\eta_p^2 = .24$, and younger adults spent a higher proportion of time studying pairs ($M = .89$, $SE = .02$) than did older adults ($M = .79$, $SE = .05$), $f(1,35) = 6.08$, $MSE = .08$, $p < .05$, $\eta_p^2 = .15$. No other effects were significant, $F < 1.5$.

Strategy use—We classified participants' reported strategies into 4 categories: (1) instances of failing to remember a strategy, (2) study avoidance (i.e., choosing to not study an item), (3) ineffective strategy use (i.e., rote repetition), and (4) effective strategy use (i.e, reported use of imagery mediators, keyword mediators, sentence generation, or relational processing). Figure 3 presents the mean proportion of each reported strategy as a function of age and value. Strategy use did not differ across blocks, so we ignored blocks in reported analyses.

Separate 2 (age) × 6 (value) ANOVAs were computed for each strategy category. No age differences were present for any strategy category, *Fs* < 1. Effective strategy use increased as value increased, which indicates that people implemented effective strategies strategically to learn high valued information, $f(5,31) = 5.17$, $MSE = .52$, $p < .001$, $\eta_p^2 = .46$. Ineffective strategy use and reported instances of failing to remember strategies did not differ as a function of value, *Fs* < 1.30. However, study avoidance decreased as item value increased, $f(5,31) = 5.24$, $MSE = .49$, $p < .001$, $\eta_p^2 = .46$. The value x age interaction was not significant for effective strategy use, $f(5,31) = 1.22$, $MSE = .04$, $p = .30$, $\eta_p^2 = .03$, or any other strategy category, *Fs* < 1.85.

In summary, younger and older adults used nearly identical strategies during study. Both age groups preferred to avoid study of low valued information and they strategically utilized normatively effective strategies to remember the highest valued information. These data are consistent with the value promotes strategy use hypothesis and argue for age equivalence in strategy production motivated by value.

Recall Performance—The mean proportion of pairs recalled across value levels are presented in Table 3 for each block and age group. On average, cued recall increased as a function of value, $f(5,31) = 9.98$, $MSE = .45$, $p < .001$, $\eta_p^2 = .22$. An effect for age was not significant, $f(1,35) = 1.72$, $MSE = 1.46$, $p = 20$, $\eta_p^2 = .05$. However, a Value x Age interaction was significant, $f(5,31) = 3.13$, $MSE = .14$, $p < .05$, $\eta_p^2 = .08$, because younger adults recalled a higher proportion of 8 to 12 point items than did older adults, *ts* > 2.2, but did not differ in memory for low point items, *ts* < 1. An effect for block approached significance, $f(1,35) = 3.71$, $MSE = .05$, $p = .06$, $\eta_p^2 = .10$, accompanied by a reliable Block x Age interaction, $f(1,35) = 5.36$, $MSE = .13$, $p < .05$, $\eta_p^2 = .13$. Age groups did not differ in performance during block 1, $t < 1.1$, but younger adults outperformed older adults during block 2, $t(34) = 2.05$, $p < .05$. The other interactions were not significant, *Fs* < 1.2.

Participants were more likely to recall word pairs when they reported using effective strategies during study (younger adults: $M = .66$, $SE = .07$; older adults: $M = .47$, $SE = .07$) relative to trials for which they reported (a) using ineffective strategies (younger adults: $M = .43$, $SE = .08$; older adults: $M = .26$, $SE = .07$); (b) avoiding studying word pairs (younger adults: $M = .03$, $SE = .01$; older adults: $M = .01$, $SE = .003$); or (c) failing to remember their strategy (younger adults: $M = .08$, $SE = .04$; older adults: $M = .03$, $SE = .02$), *ts* > 4.6.

It is possible that elaborative rehearsal following strategy production or selective use of subsequent self-testing strategies (see review by Hertzog, in press) would amplify the recall benefits of effective strategy use for high-value items. The mean proportions of pairs recalled after study with ineffective or effective strategies are presented in Table 4. There was no sign of an amplification effect; use of high-quality strategies improved recall similarly regardless of the point value assigned to items.

For statistical analysis we collapsed across high (8 to 12-point) and low (2 to 6-point) valued word pairs to smooth data (avoiding effects of missing recall data for some point values for participants). Complete data for 15 younger adults and 16 older adults were analyzed in a 2 (value: low vs. high) × 2 (strategy use: effective vs. ineffective) × 2 (Age) repeated measures ANOVA. There were reliable main effects for age, $f(1,29) = 5.90$, $MSE = .1.61$, $p < .05$, $\eta_p^2 = .17$, and strategy use, $f(1,29) = 18.72$, $MSE = 1.00$, $p < .001$, $\eta_p^2 = .39$. Value had no significant main effect, $f(1,29) = 2.42$, $MSE = .05$, $p =.13$, $\eta_p^2 = .08$, but there was a reliable Value x Age interaction, reproducing the effect reported earlier. Most important, the Value X Strategy use interaction and the Strategy use X Age interaction were not significant, *Fs* < 1. The three-way interaction was also not significant, $f(1,29) = 3.09$, $MSE = .07$, $p =.09$, $\eta_p^2 = .10$.

These results show that strategy use resulted in global improvements to memory regardless of value. Thus, memory enhancement by value was due to the selective use of effective strategies to study high value material. However, age differences in memory still occurred for cued recall of high value material, in contrast to earlier work on value-directed memory in free recall (Castel, 2008).

Experiment 2

Although the previous results suggest a fundamental difference in value-directed memory for free recall versus associative recall, the differences in memory performance we observed relative to earlier work by Castel and colleagues may reflect the complexity of the new task environment used in the current experiments.

The current experiments differed in a variety of ways from earlier free-recall experiments. The previous method for examining value-based remembering (Castel et al. 2002; Watkins & Bloom, 1999) requires learners study multiple lists containing words assigned different point values. During study, each word and its point value are presented together for a short duration (e.g., 2 sec). Participants study each word sequentially and after studying an entire list, participants are instructed to freely recall as many words as they can remember.

In contrast, the current experiments used a paradigm in which people had to separately search for value and word pairs. Each trial also involved studying up to six different items in a grid, rather than serial presentation of single items, and item restudy was encouraged by the generous time limits. The age differences in value-based remembering we observed in Experiment 1 could be due to (a) the increased cognitive load required to identify value and study valuable information in our information search paradigm, or (b) the increased opportunity for metacognitively guided control of study (Hertzog, in press) compared to earlier studies. Using our information search paradigm, Experiment 2 randomly assigned participants to study lists of words or paired-associates. If the complex task was responsible for age differences in value-directed memory, one would expect age differences to emerge for lists of individual words in the present task environment. Conversely, if age differences in value-based remembering are due to an associative recall deficit, then age differences in value-based remembering should only be observed when participants are learning new associations.

Experiment 2 also evaluated a second hypothesis for the age differences observed in Experiment 1. Full age equivalence in memory selectivity tasks emerge after experiencing multiple tests, usually by the 4^{th} study list. Perhaps older adults need more task experience than younger adults to adapt their regulatory strategies to selectively encode valuable information (Castel, 2008). To test this hypothesis, we used four study-test blocks.

We also evaluated the hypothesis that declines in general fluid intelligence (Gf) may impact effective strategy implementation for older adults. Age related differences in performance sometimes occur in tasks even when both younger and older adults are given an effective strategy to use (Lemaire, 2010; Siegler & Lemaire, 1997). Gf appears to moderate strategy execution for younger adults in some tasks (e.g., Nusbaum & Silvia, 2011). In the current experiments, low-Gf older adults may have been less effective at implementing mediational strategies. To evaluate this hypothesis, we measured Gf using Raven's Progressive Matrices. If Gf moderates the effectiveness of strategy use for older adults, then high-Gf participants should benefit more from use of effective strategies than low-Gf participants.

Finally, strategy use was examined using retrospective strategy reports that occurred only after the final study-test block (Block 4) for items studied in the final block. This allowed us to avoid possible reactive effects of making concurrent strategy reports on value-directed study behaviors and to eliminate possible recall contamination due to possible rehearsal and retrieval practice during the strategy report.

Method

Participants—Sixty-two older adults (38 females, 24 males, *M* Age = 69 years old, Age range = 60-80) and seventy-four younger adults (48 females, 25 males, *M* Age = 20 years old, age range = 18-33) from the Georgia Tech ($N = 39$) and the University of Alabama Huntsville ($N = 35$) participated in this experiment. Participants were randomly assigned to either the word learning group (Younger: $N = 39$, Older: $N = 32$) or paired associate learning group (Younger: $N = 35$, Older: $N = 31$). All older adults had self-reported good health, computer proficiency, and at least a high school diploma. The majority of older adults were college educated (Bachelor's Degree = 71%, graduate degree = 32%). Older adults had higher vocabulary knowledge as measured by the Advanced Vocabulary Test (Ekstrom, French, Harman, & Dermen, 1976), but displayed lower scores on perceptual speed measures (composite letter and pattern comparison tasks, Salthouse & Babcock, 1991) and on a measure of Gf (Raven's progressive matrices, Raven, Raven, & Court, 1998), all $Fs > 17$, $p < .001$. None of these measures differed between the word learning and paired associate learning groups, $Fs < 1$.

Materials & Procedure—The materials and procedure were similar to Experiment 1a with the following exceptions. First, the study items consisted of either word pairs or single words. The words participants studied in the word learning group consisted of the same target words used in each paired associate item. Participants who studied word pairs completed a cued recall test as in Experiment 1. Participants in the word learning group completed a free recall test at the end of each block in which they were asked to type as many words as they could remember from the study phase of that block. Second, four study-test blocks were administered. Third, the number of trials in each block was reduced from 10 to 8 (reducing the number of items per test from 60 to 48). The time limit for each trial was identical for the word learning and paired associate learning groups (25 s for younger adults and 50 s for older adults).

Fourth, after the final test participants in the paired associate learning groups completed retrospective strategy reports (Dunlosky & Hertzog, 2001) for items studied in the final study-test block using the same strategy report options as in Experiment 1b. The instructions specified that participants should only report the strategy or strategies they used to study items during the final block. Each grid was presented in the order that participants had originally studied them. Participants viewed an enlarged cell of the 6 item study array which contained both the cue and target word that was presented in that location during study, and were prompted to give strategy reports.

After participants completed their strategy reports, they completed the Letter Comparison, Pattern Comparison, the Advanced Vocabulary Test and a computerized version of Raven's Progressive Matrices adapted from Stanovich and Cunningham (1993), consisting of 18 trials ordered in ascending difficulty.

Results & Discussion

Analyses were conducted separately for word learning and paired associate learning groups. Unless noted otherwise, analyses consisted of a 2 (Age) × 4 (Block) × 6 (Value) repeated measures ANOVAs.

Study-time Allocation—The mean proportion of trials for each block for which the value array was selected first is presented in Table 1. Consistent with previous experiments, preference for discovering value early increased across blocks for both the word learning, $f(3,61) = 19.16$, $MSE = .58$, $p < .001$, $\eta_p^2 = .22$, and paired-associate learning groups, $f(3,67) = 9.15$, $MSE = .35$, $p < .001$, $\eta_p^2 = .35$. Effects for age and the interaction effects were not significant for either group, Fs < 1.7.

Mean item selection is presented in Table 5 as a function of value, block, and learning group. Participants in the word learning group were more likely to restudy high valued words, $f(5,65) = 82.87$, $MSE = 1237.54$, $p < .001$, $\eta_p^2 = .55$, and older adults selected words more times for study than younger adults, $f(1,69) = 4.44$, $MSE = 54709.62$, $p < .05$, $\eta_p^2 = .06$. A Block x Value interaction, $f(15, 55) = 3.55$, $MSE = 9.70$, $p < .001$, $\eta_p^2 = .05$, reflected decreasing selection across blocks in 2-point and 8-point items but greater selection of 12-point items. Selection rates for other values did not differ reliably across blocks.

For the paired-associate group, item selection behavior varied by age, $f(1,64) = 8.74$, $MSE = 18260.12$, $p < .001$, $\eta_p^2 = .88$, block, $f(3,62) = 5.34$, $MSE = 32.71$, $p < .01$, $\eta_p^2 = .55$, and value, $f(5,60) = 76.59$, $MSE = 221.07$, $p < .001$, $\eta_p^2 = .54$. These effects reflect higher item selection for high than low valued items, higher reselection for older adults than younger adults, and a decrease in item selection across study-test blocks. No interactions were significant, *Fs* < 1.26.

The mean proportion of total time allocated to studying words or word pairs are presented in Figure 4. People allocated a greater proportion of time to high than low value words, $f(5,65) = 90.99$, $MSE = 1.21$, $p < .001$, $\eta_p^2 = .57$, and word pairs, $f(5,60) = 5.34$, $MSE = 32.71$, $p < .01$, $\eta_p^2 = .55$. Study time increased across blocks for both words, $f(3,67) = 5.55$, $MSE = .01$, $p < .01$, $\eta_p^2 = .07$, and word pairs, $f(3,62) = 9.23$, $MSE = .02$, $p < 0.01$, $\eta_p^2 = .13$, and younger adults allocated a greater proportion of time overall to studying words, $f(1,69) = 13.92$, $MSE = .38$, $p < .001$, $\eta_p^2 = .17$, and word pairs, $f(1,64) = 9.81$, $MSE = .17$, $p < .01$, $\eta_p^2 = .13$. A Block x Value interaction was also significant for both the word learning, $f(15,55) = 3.96$, $MSE = .01$, $p < .01$, $\eta_p^2 = .05$, and paired associate learning groups, $f(15,50) = 2.36$, $MSE = .01$, $p < .05$, $\eta_p^2 = .04$. These interactions occurred because study-time was greater for 10-12 point words and word pairs, *Fs* > 2.12, but did not differ for other values across blocks. An Age x Value interaction was also significant for the paired associate learning group, $f(5,60) = 2.49$, $MSE = .05$, $p < .01$, $\eta_p^2 = .04$, which occurred because younger adults allocated a higher proportion of their available time to studying 12 point pairs, $t(64) = 2.56$, $p < .05$, than did older adults. No other effects were significant, *Fs* < 1.08.

In summary, younger and older adults again used their study time in an identical fashion. They both avoided study of low valued information and chose to selectively utilize effective encoding strategies to learn high valued information.

Strategy use—The mean proportion of each strategy reported following block 4 for the paired-associate learning group is presented in Figure 5. Value had robust effects on reports of avoiding study, $f(5,60) = 41.72$, $MSE = 1.99$, $p < .001$, $\eta_p^2 = .40$, and reported use of effective encoding strategies, $f(5,60) = 41.72$, $MSE = 1.99$, $p < .001$, $\eta_p^2 = .40$. No reliable age differences were detected for reported study avoidance, ineffective strategy use, or effective strategy use. However, older adults were slightly more likely to report forgetting their strategy for word pairs, $f(1,64) = 4.02$, $MSE = .26$, $p < .05$, $\eta_p^2 = .06$, as found by Dunlosky and Hertzog (2001). No other effects were significant for any strategy category, $Fs < 1.6$.

These results suggest minimal reactive effects in Experiment 1B of prompting participants to report their strategies after each trial. Instead, they suggest that people spontaneously use effective encoding strategies when studying high valued information and prefer to avoid study of low valued information.

Recall Performance—Table 6 presents the mean proportion of recall as a function of value and block for the word learning and paired associate learning groups. People recalled more high than low valued words, $f(5,65) = 101.29$, $MSE = 6.96$, $p < .001$, $\eta_p^2 = .60$, and paired associates, $f(5,60) = 50.17$, $MSE = 4.56$, $p < .001$, $\eta_p^2 = .44$. Younger adults recalled more words, $f(1,69) = 3.88$, $MSE = .94$, $p < .05$, $\eta_p^2 = .05$, and word pairs, $f(1,64) = 15.66$, $MSE = 8.17$, $p < .001$, $\eta_p^2 = .20$, than older adults and recall improved across blocks for both words, $f(3,67) = 6.18$, $MSE = .21$, $p < .001$, $\eta_p^2 = .08$, and paired associates, $f(3,62) = 15.56$, $MSE = .52$, $p < .001$, $\eta_p^2 = .20$. A Block x Value interaction occurred for words, $f(15,55) = 1.74$, $MSE = .02$, $p < .05$, $\eta_p^2 = .03$, and paired associates, $f(15,50) = 1.93$, $MSE = .04$, $p < .05$, $\eta_p^2 = .03$, because memory for high valued items was greater in later blocks than in earlier blocks. Most important, a significant Age x Value interaction occurred for paired associates, $f(5,60) = 3.54$, $MSE = .32$, $p < .01$, $\eta_p^2 = .05$, but not for words, $F < 1.3$. This interaction reflects an age-deficit in value-based remembering due to younger adults outperforming older adults on memory for high valued paired associates (10 and 12 points), $ts > 3.4$, but not on lower valued pairs (2 to 8 point items), $ts < 2.4$. In contrast, younger and older adults did not differ in memory for the highest valued words in the word list task, $t < 1$.

The larger sample size in Experiment 2 also allowed us to examine the relationship between early value discovery, reflecting early adoption and use of a value-based agenda (Table 1), and value-based remembering. Figure 6 presents the Pearson correlations (*r*) between participants' average proportion of early value discovery and their proportion of correct recall for each value level. Early value discovery was associated positively with memory for high valued items and negatively with memory for low valued items. These correlations did not differ systematically across blocks or learning materials.

In summary, early value discovery predicted value-based remembering of information for both age groups. Nevertheless, age differences in value-based remembering occurred for paired associate learning but not word learning, even after four blocks of study-test experience.

The effects of aging and Gf on strategy execution. Table 4 reports mean recall performance for word pairs studied with effective and ineffective strategies during Block 4. To simultaneously evaluate the effects of aging and Gf on strategy execution, we computed a multilevel mixed effects model predicting the proportion of pairs recalled during this final block of study, using STATA (StataCorp, 2013), assuming a Gaussian (normal) distribution of residuals. Fixed effects of age (older adults coded as 0), point value, Gf (Raven's score), the proportion of effective strategies reported, and all interaction terms were included in this model with a random subject-level intercept. Value, Gf, and strategy use were group mean centered. Only items reported to have been studied were included in the model to allow us to compare the effects of effective strategy use to ineffective strategy use. Random effects on value slopes did not improve the model fit ($ps > .26$), and were not included in the final model which is summarized in Table 7.

The model revealed that recall performance was 24% higher for younger adults than older adults ($\beta = .24$) and it increased by 5% for every increase in point value ($\beta = .05$). The effects of value on recall were moderated by participants Gf (Value x Gf: $\beta = .01$) and by effective strategy use (Value x Strategy use: $\beta = .18$). An Age x Value x Effective strategy use ($\beta = -.21$), a Value x Gf x Effective strategy use ($\beta = .05$), and the 4-way interactions were also significant ($\beta = -.05$). To decompose this higher order interaction, marginal means of the regression equation were plotted separately for younger and older adults at 1 SD above and below the mean for value, Gf, and effective strategy use (see Figure 7). The 4-way interaction occurred because older adults with high-Gf who used effective strategies had enhanced recall for high-value items (relative to low-value items). In fact, these older participants remembered high valued items at the same level as younger adults indicating the associative memory deficit was not present for high-Gf participants who utilized effective strategies.

General Discussion

The current experiments examined age differences in study-time allocation and strategy use during an associative value-based remembering task. The results revealed younger and older adults use nearly identical self-regulated study strategies. They both prioritized valuable information for study and spontaneously used effective encoding strategies like the generation of interactive image mediators to learn valuable information, while tending to limit study of low valued information. These results are consistent with a hypothesis of age equivalence in agenda-based self-regulation (Hertzog, in press).

Despite similar self-regulated study processes and enhanced memory for high-valued items for both age groups, reliable age differences in associative value-based remembering were detected. Older adults were less effective than younger adults at remembering the highest valued paired associates (8 to 12-point items), but did not differ in memory for low valued pairs (2 to 6-point items). These results are inconsistent with evidence from value-directed free recall paradigms (e.g. the word learning group in Experiment 2) that typically yield age equivalence in memory for high valued words (see Castel, 2008).

Why do age differences occur for value-based remembering of associative information but not item learning? One hypothesis is that these differences are due to different task affordances (Bottiroli, Dunlosky, Guerini, Cavallini, & Hertzog, 2010). List learning tasks may afford use of relational strategies (e.g., use of imagery or sentence generation combining words in a list) that leads to selective reorganization and rehearsal of high-value information within lists. Older adults spontaneously use relational organizational strategies in free recall tasks where value is not manipulated (e.g., Hertzog, McGuire, & Lineweaver, 1998; Hertzog et al. 2009). They also selectively re-rehearse high value words at the end of their study period (Castel et al., 2013), which is consistent with use of value-directed organizational encoding. The fact that we observed spared value-based remembering across multiple grids implies that people of all ages may use relational strategies across grids to organize and rehearse high-value items as a chunk or chunks, a hypothesis that needs to be tested in future experiments.

Associative memory tasks on the other hand, do not easily afford grouping and rehearsing items according to value. Effective strategy use is focused on individual associations, and cued-recall tests are ordered by the computer program, foiling value-based retrieval search. Bailey, Dunlosky, and Hertzog (2014)'s training study is consistent with the argument that the two types of strategy are not highly commensurate. Older individuals trained to use subjective organization for sequentially presented words in a list only showed transfer benefits (increased strategy use with enhanced recall) on tasks with similar encoding requirements (working memory span tasks). They did not show transfer benefits from this type of strategy training to paired-associate learning despite high levels of reported strategy use in that task.

In the current experiments, strategy use improved associative value-based remembering for both age groups, but if anything it amplified age differences in memory for high-value items. One possible explanation is that strategy production did not translate into equivalent strategy implementation (Lemaire, 2010). Older adults may have generated less effective mediators and as a result they failed to remember them at testing. Alternatively, they may have generated equally effective mediators, but failed to retrieve them due to an associative retrieval deficit. It is also possible that older adults retrieved mediators for high quality items but failed to decode the mediator to recover the correct target word. Both mediator retrieval and decoding have been found to be impaired with aging in tasks where mediator reports can distinguish between these alternative outcomes (Dunlosky et al., 2005; Hertzog, Fulton, Mandviwala, & Dunlosky, 2013). Finally, younger adults may be more effective at selective self-testing late in the study period, given that testing-induced retrieval practice is known to enhance memory (Maddox & Balota, 2012).

Our findings that self-regulatory behaviors were similar for the two age groups does not imply that older adults cannot or will not learn to compensate for associative memory deficits in this task by improving their self-regulation strategies. From a compensation viewpoint, the observed value-based associative memory deficit indicates that older adults may need to adjust their strategic behavior even further to overcome age-related associative memory deficits and achieve equivalent remembering of high-value items. It is possible that additional task practice would improve older adults' access to high-value mediators. Simple encoding strategy practice or even training may not suffice (cf. Shing et al., 2010); metacognitive interventions to encourage active self-regulation of compensatory encoding and retrieval strategies (e.g., through the use of self-testing strategies during encoding; Dunlosky, Kubat-Silman, & Hertzog, 2003) may be required (see Cavallini et al., 2010).

This perspective helps to frame the interaction of Gf with effective strategy use on value-based remembering found in Experiment 2. Older adults with high-Gf who used mediational strategies had enhanced value-based remembering for associative information compared to older adults with lower Gf who reported using similar encoding strategies, and demonstrated no age-related associate memory deficit for high valued information. Perhaps high-Gf older adults were more capable of generating high quality mediators, had potentiated access to mediators at test, or were more adept at creating adaptive metacognitive control strategies in the associative learning task.

In summary, we found that the self-regulated study behaviors deployed to learn valuable associative information are essentially equivalent for younger and older adults. Both age groups prioritized valuable associative information for study and allocated more time to learning that information. These results allay concerns that age-related cognitive decline impairs agenda-based regulation. Older and younger adults also selectively used effective encoding strategies to learn high valued information. Both these regulatory strategies improved value-based remembering. However, these self-regulatory behaviors were not sufficient to eliminate associative memory deficits that occur for older adults for valuable information. Apparently older adults require either (a) better implementation or augmentation of effective strategies or (b) even more elaborate compensatory strategies to overcome age-related deficits in associative learning for high-value items.

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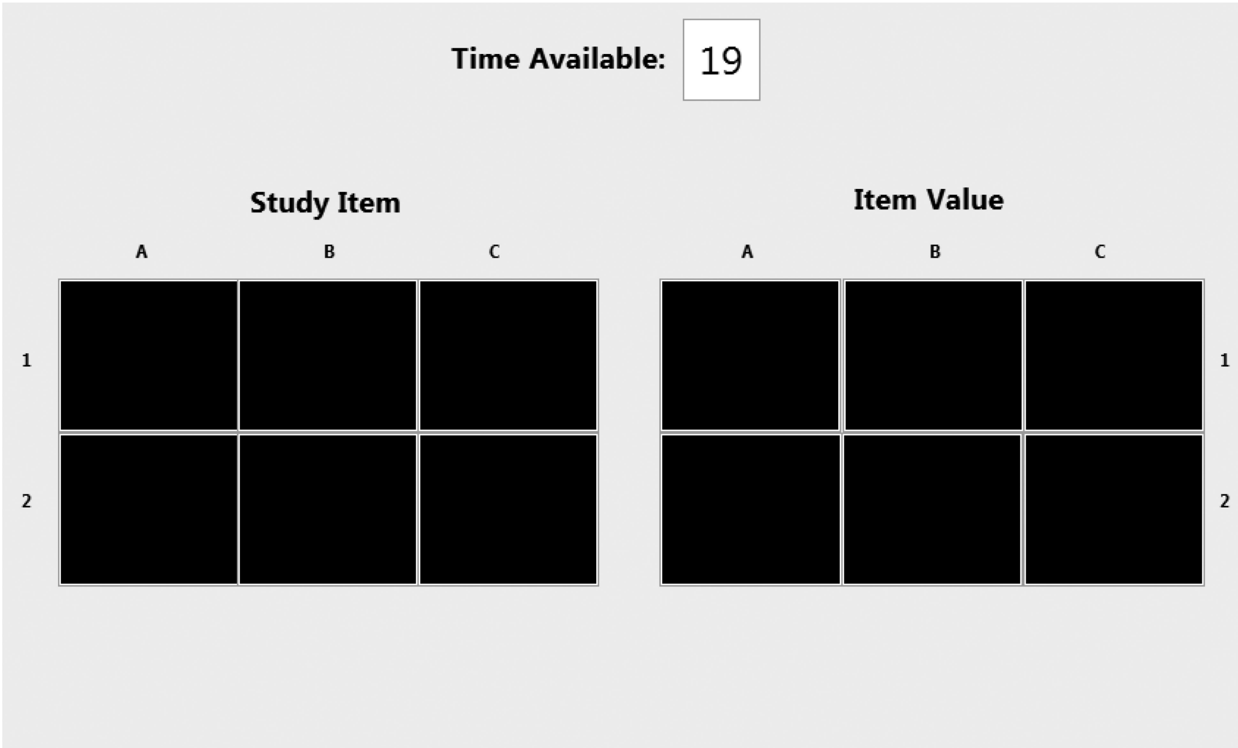

Figure 1.
Illustration of a typical study trial.

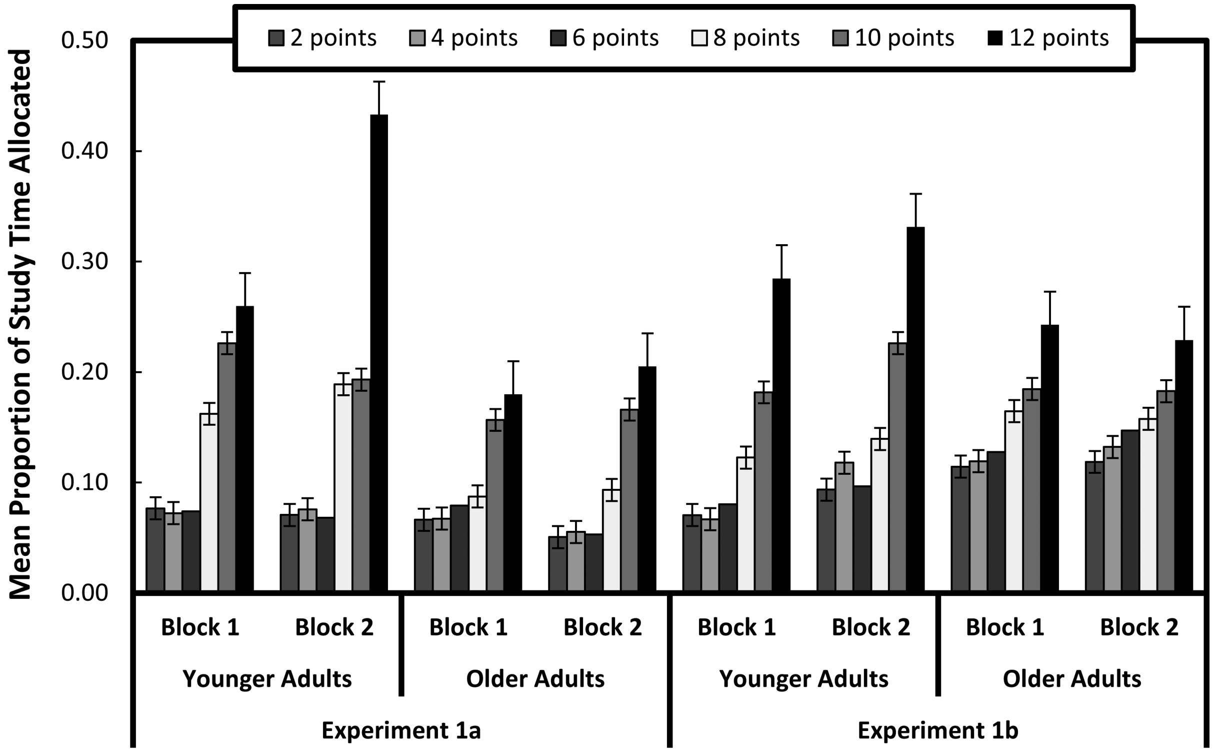

Figure 2.

Mean proportion of total time allocated to studying word pairs in Experiment 1a with no strategy reports and Experiment 1b with strategy report as a function of age.

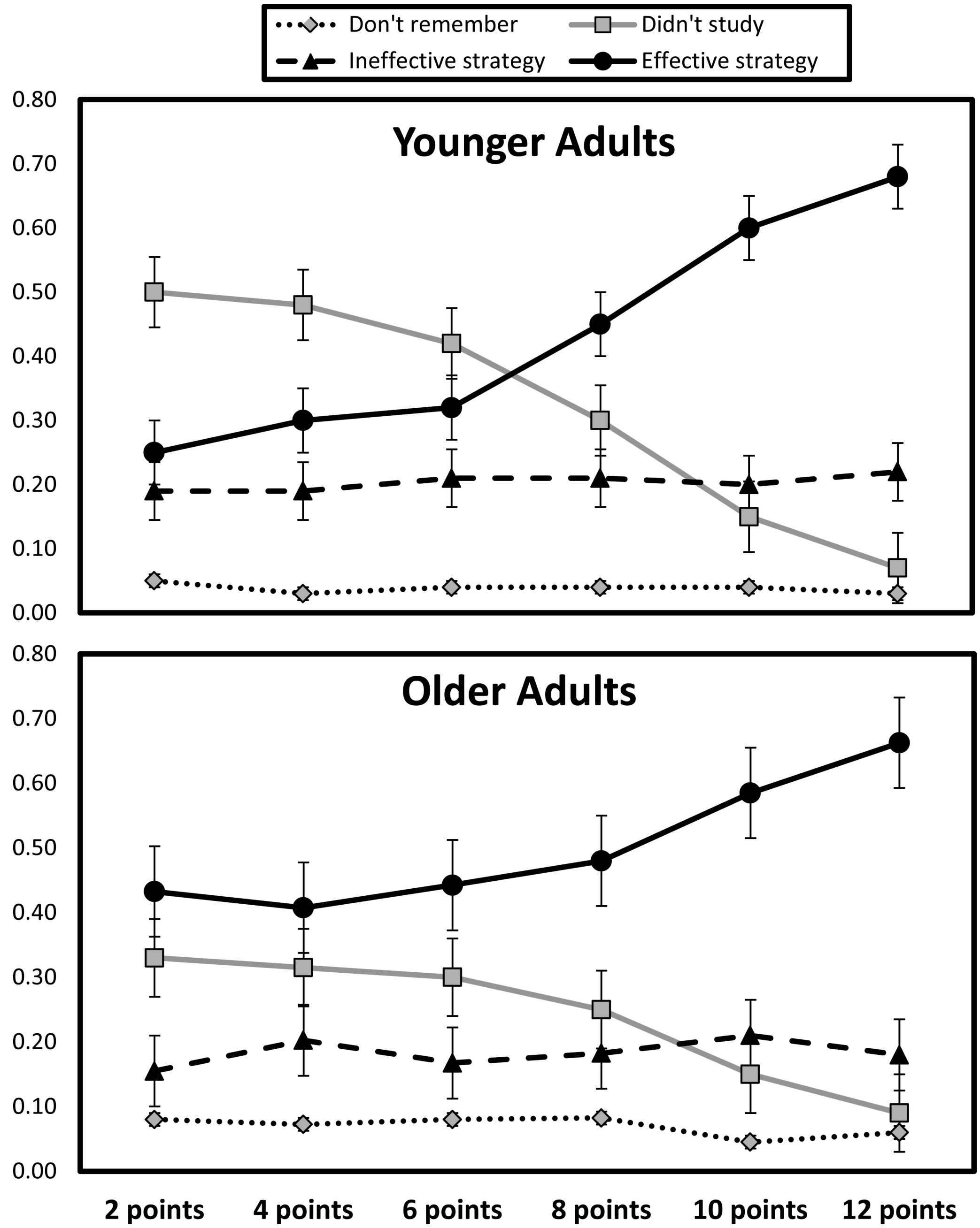

Figure 3.
Mean proportion reported strategy use for younger (top panel) and older (bottom panel) adults in Experiment 1b.

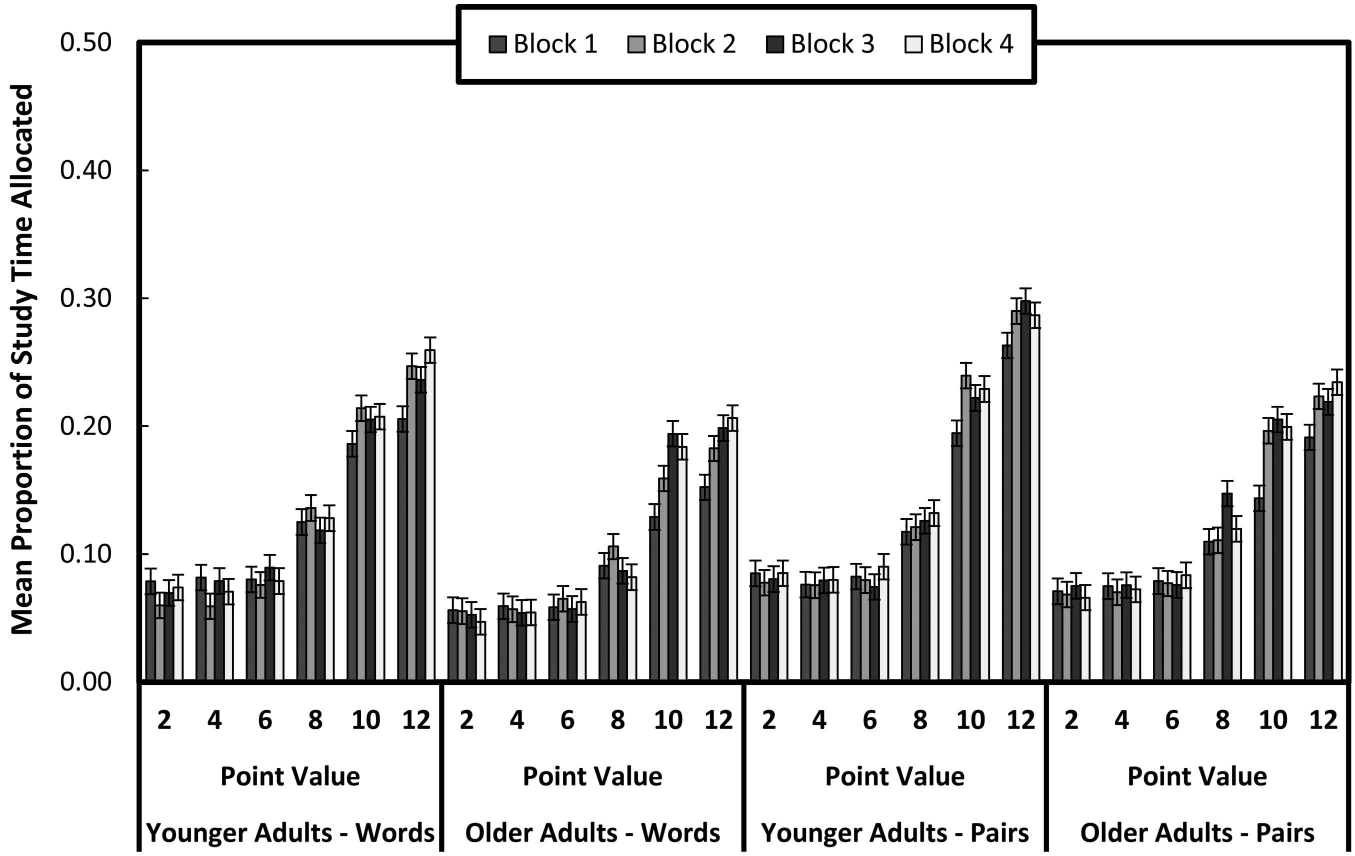

Figure 4.

Mean proportion of total time allocated to studying words and word pairs across blocks for younger and older adults in Experiment 2.

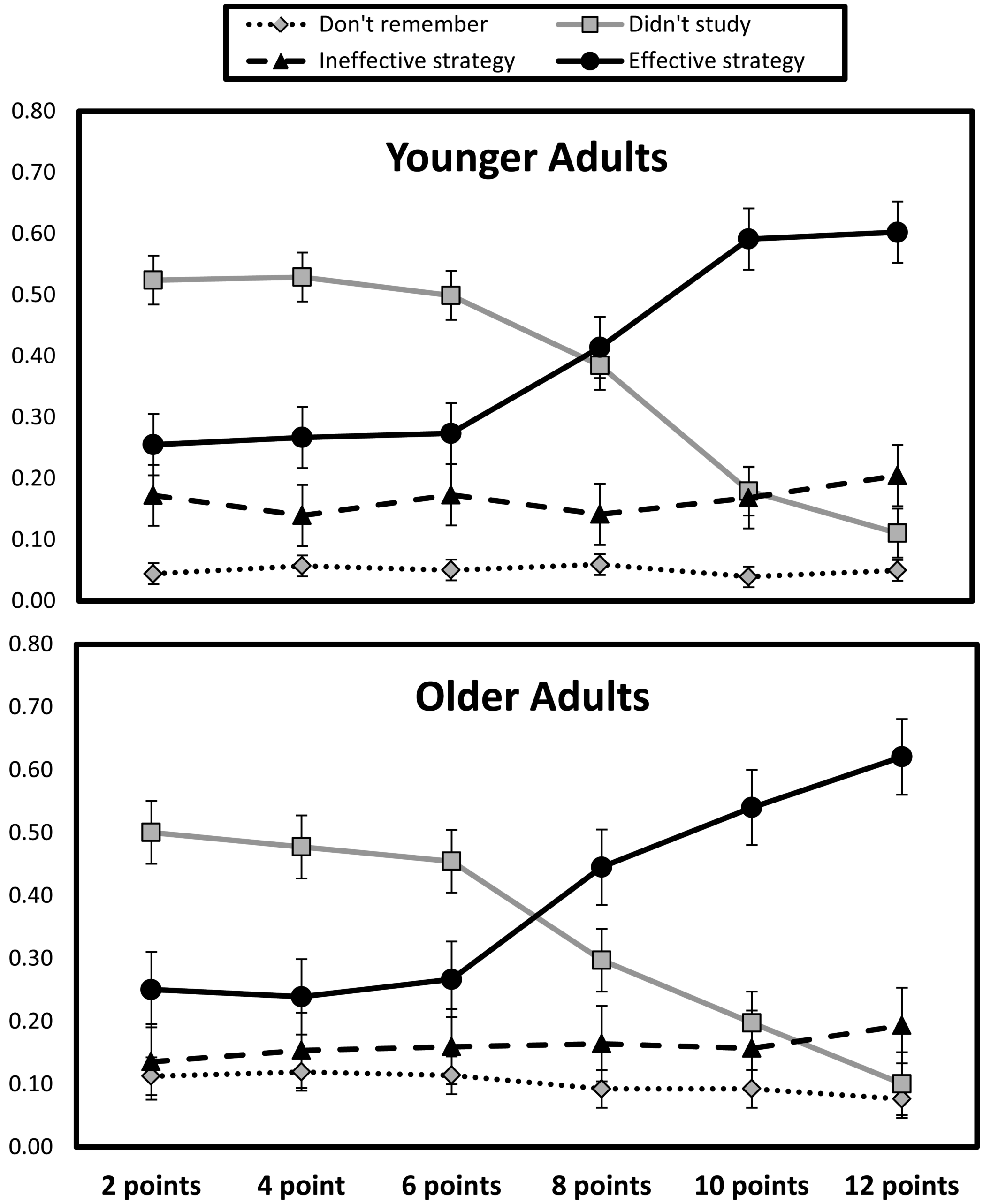

Figure 5.

Mean proportion reported strategy use for younger (top panel) and older (bottom panel) adults in Experiment 2.

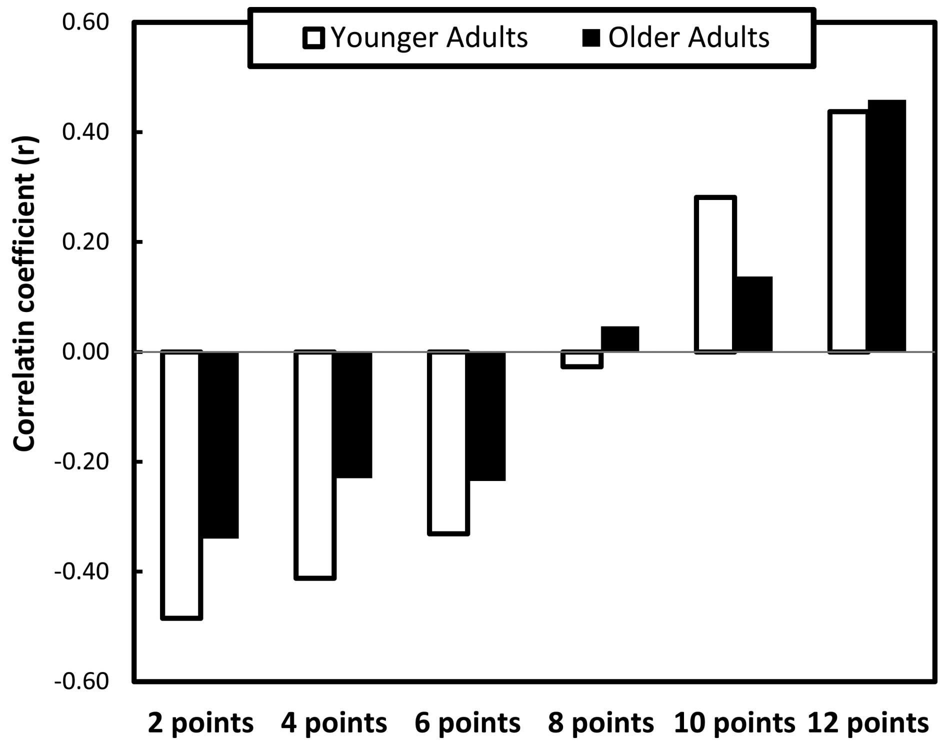

Figure 6.

Correlations (*r*) between younger and older adults' average proportion of early value discovery (accessing the value array first on each trial) and average recall performance as a function of value in Experiment 2.

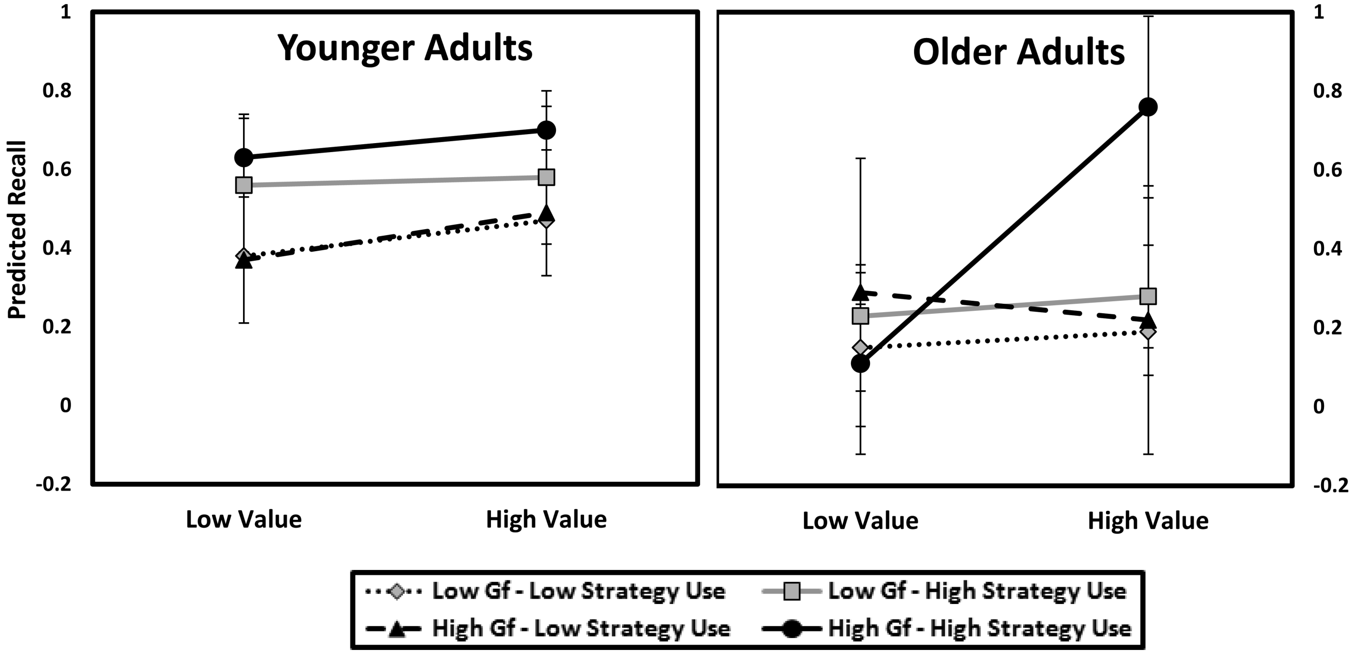

Figure 7.

Predicted Marginal Means (and 95% confidence intervals) of paired associate recall for younger and older adults as a function of high and low Gf, high and low effective strategy use, and high and low point value for paired associates in Experiment 2. Low and high values for each variable represents estimates at 1 SD above and below the mean for each variable.

Table 1

Mean proportion of times the value array was accessed first on each trial across blocks for younger and older adults in each Experiment.

	Younger Adults				Older Adults			
	Block 1	**Block 2**	**Block 3**	**Block 4**	**Block 1**	**Block 2**	**Block 3**	**Block 4**
Experiment 1a	.41 (.07)	.52 (.07)	-	-	.23 (.07)	.45 (.10)	-	-
Experiment 1b	.31 (.06)	.54 (.08)	-	-	.26 (.07)	.35 (.08)	-	-
Experiment 2								
Word Learning	.29 (.04)	.49 (.05)	.46 (.05)	.50 (.05)	.26 (.06)	.42 (.07)	.47 (.07)	.46 (.07)
Pair Learning	.36 (.05)	.48 (.05)	.48 (.06)	.54 (.06)	.26 (.05)	.38 (.07)	.42 (.06)	.41 (.07)

Note. Standard errors of the means are in parenthesis.

Table 2

Mean item selection as a function of point value across trials for each block in Experiment 1a and Experiment 1b where participants made concurrent strategy reports.

	Younger Adults		Older Adults	
Value	**Block 1**	**Block 2**	**Block 1**	**Block 2**
Experiment 1a				
2 points	2.20 (.22)	1.56 (.29)	3.40 (.46)	2.17 (.31)
4 points	2.20 (.27)	1.49 (.28)	3.47 (.49)	2.27 (.32)
6 points	2.34 (.29)	1.57 (.25)	3.66 (.51)	2.31 (.38)
8 points	3.63 (.43)	2.13 (.43)	3.66 (.49)	2.61 (.34)
10 points	4.44 (.51)	2.80 (.38)	4.54 (.62)	3.83 (.70)
12 points	4.80 (.44)	3.31 (.36)	4.76 (.41)	4.25 (.66)
Experiment 1b				
2 points	2.68 (.30)	2.49 (.35)	3.51 (.36)	2.76 (.35)
4 points	2.62 (.26)	2.84 (.64)	3.48 (.34)	2.53 (.28)
6 points	2.86 (.26)	3.08 (.61)	3.59 (.36)	2.82 (.29)
8 points	3.23 (.29)	3.05 (.46)	3.66 (.34)	3.26 (.40)
10 points	3.42 (.43)	2.95 (.32)	3.80 (.33)	3.70 (.39)
12 points	3.70 (.40)	3.28 (.34)	4.06 (.29)	4.09 (.37)

Note. Standard errors of the means are in parenthesis.

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Table 3

Mean proportion of paired associates recalled for each age group as a function of point value and block in Experiment 1a and 1b.

	Younger Adults		Older Adults	
Value	**Block 1**	**Block 2**	**Block 1**	**Block 2**
Experiment 1a				
2 points	.10 (.03)	.15 (.05)	.06 (.02)	.06 (.04)
4 points	.11 (.04)	.13 (.04)	.06 (.03)	.05 (.03)
6 points	.10 (.03)	.14 (.05)	.08 (.03)	.05 (.03)
8 points	.28 (.05)	.32 (.07)	.10 (.04)	.16 (.06)
10 points	.28 (.05)	.47 (.07)	.18 (.05)	.23 (.07)
12 points	.39 (.05)	.66 (.06)	.27 (.06)	.35 (.07)
Experiment 1b				
2 points	.25 (.07)	.34 (.07)	.33 (.08)	.30 (.08)
4 points	.31 (.07)	.38 (.08)	.32 (.07)	.26 (.07)
6 points	.35 (.06)	.42 (.07)	.35 (.08)	.26 (.07)
8 points	.51 (.06)	.62 (.07)	.28 (.07)	.29 (.07)
10 points	.58 (.08)	.59 (.08)	.35 (.07)	.41 (.06)
12 points	.58 (.09)	.64 (.07)	.35 (.07)	.41 (.08)

Note. Standard errors of the means are in parenthesis.

Table 4

Mean proportion recall as a function of value for items studied with ineffective and effective strategies in Experiment 1b and Experiment 2 for each age group.

	Ineffective Strategies		Effective Strategies	
Value	**Younger Adults**	**Older Adults**	**Younger Adults**	**Older Adults**
Experiment 1b				
2 points	.32 (.11)	.19 (.08)	.63 (.09)	.49 (.08)
4 points	.39 (.11)	.31 (.08)	.68 (.10)	.44 (.07)
6 points	.29 (.08)	.29 (.08)	.66 (.08)	.43 (.09)
8 points	.55 (.11)	.14 (.07)	.74(.06)	.44 (.08)
10 points	.51 (.12)	.21 (.07)	.70 (.07)	.45 (.06)
12 points	.32 (.09)	.27 (.09)	.66 (.08)	.49 (.07)
Experiment 2				
2 points	.09 (.06)	.04 (.04)	.59 (.09)	.19 (.07)
4 points	.27 (.10)	.10 (.07)	.55 (.09)	.31 (.09)
6 points	.24 (.09)	.02 (.02)	.54 (.08)	.18 (.07)
8 points	.12 (.08)	.07 (.07)	.70(.07)	.36 (.08)
10 points	.28 (.09)	.10 (.05)	.71 (.05)	.35 (.06)
12 points	.29 (.08)	.19 (.09)	.68 (.06)	.42 (.07)

Note. Standard errors of the means are in parenthesis. Recall was computed for only pairs selected for study that participants reported studying with either ineffective or effective strategies

Table 5

Mean item selection as a function of point value across trials for each block in Experiment 2 as a function of learning material.

	Younger Adults				Older Adults			
Value	**Block 1**	**Block 2**	**Block 3**	**Block 4**	**Block 1**	**Block 2**	**Block 3**	**Block 4**
Word Learning								
2 points	3.89 (.38)	3.05 (.35)	3.34 (.37)	3.06 (.33)	4.78 (.50)	4.60 (.62)	4.57 (.68)	4.27 (.61)
4 points	3.59 (.39)	3.02 (.32)	3.17 (.29)	3.04 (.33)	4.67 (.46)	4.69 (.56)	4.38 (.56)	4.06 (.57)
6 points	3.75 (.33)	3.55 (.34)	3.38 (.36)	3.06 (.30)	4.85 (.55)	4.88 (.60)	4.63 (.59)	4.84 (.64)
8 points	5.46 (.50)	6.03 (.72)	4.96 (.63)	4.70 (.61)	6.58 (.75)	6.95 (.87)	6.23 (.77)	5.55 (.85)
10 points	6.84 (.51)	7.87 (.65)	7.13 (.64)	6.86 (.70)	8.08 (.96)	8.96 (1.10)	9.38 (1.09)	9.23 (.93)
12 points	6.86 (.45)	8.01 (.64)	7.87 (.68)	7.06 (.65)	8.63 (.96)	9.59 (1.10)	9.79 (1.01)	9.55 (.91)
Paired Associate Learning								
2 points	2.48 (.26)	2.36 (.26)	2.07 (.23)	1.94 (.18)	3.75 (.39)	2.86 (.30)	2.90 (.29)	2.83 (.28)
4 points	2.47 (.33)	2.26 (.24)	2.10 (.21)	1.96 (.37)	3.80 (.37)	3.14 (.33)	2.90 (.27)	2.61 (.26)
6 points	2.58 (.34)	2.38 (.29)	1.91 (.22)	2.13 (.40)	3.79 (.40)	3.26 (.37)	2.76 (.28)	2.99 (.29)
8 points	3.31 (.39)	2.79 (.28)	2.59 (.22)	2.53 (.43)	4.50 (.43)	3.52 (.40)	3.90 (.31)	3.43 (.33)
10 points	4.19 (.40)	4.23 (.36)	3.79 (.38)	3.52 (.37)	4.71 (.38)	4.95 (.45)	4.63 (.37)	4.91 (.41)
12 points	4.45 (.37)	4.51 (.34)	4.06 (.34)	3.74 (.29)	5.26 (.46)	5.50 (.58)	4.81 (.37)	5.25 (.44)

Note. Standard errors of the means are in parenthesis.

Table 6

Mean proportion of words and paired associates recalled for each age group as a function of point value and block in Experiment 2.

	Younger Adults				Older Adults			
Value	**Block 1**	**Block 2**	**Block 3**	**Block 4**	**Block 1**	**Block 2**	**Block 3**	**Block 4**
Word Learning								
2 points	.12 (.02)	.15 (.03)	.14 (.03)	.13 (.03)	.07 (.02)	.09 (.03)	.08 (.02)	.10 (.03)
4 points	.11 (.02)	.18 (.03)	.13 (.02)	.15 (.03)	.10 (.02)	.09 (.02)	.11 (.03)	.11 (.03)
6 points	.16 (.03)	.14 (.03)	.15 (.03)	.18 (.04)	.09 (.02)	.13 (.03)	.12 (.03)	.14 (.04)
8 points	.24 (.03)	.28 (.03)	.30 (.04)	.22 (.04)	.18 (.03)	.22 (.04)	.21 (.04)	.18 (.04)
10 points	.36 (.04)	.43 (.03)	.47 (.03)	.47 (.05)	.27 (.04)	.33 (.05)	.38 (.05)	.35 (.05)
12 points	.44 (.04)	.48 (.03)	.53 (.04)	.53 (.05)	.41 (.05)	.49 (.05)	.53 (.04)	.53 (.05)
Paired Associate Learning								
2 points	.14 (.03)	.14 (.03)	.19 (.05)	.17 (.04)	.08 (.02)	.06 (.03)	.09 (.04)	.06 (.02)
4 points	.11 (.03)	.15 (.04)	.20 (.04)	.21 (.04)	.07 (.02)	.09 (.04)	.07 (.03)	.07 (.03)
6 points	.11 (.03)	.18 (.04)	.18 (.04)	.20 (.04)	.07 (.03)	.08 (.03)	.11 (.04)	.04 (.02)
8 points	.25 (.04)	.31 (.05)	.37 (.05)	.31 (.05)	.09 (.03)	.18 (.05)	.24 (.05)	.17 (.05)
10 points	.39 (.04)	.52 (.05)	.54 (.05)	.48 (.05)	.17 (.04)	.26 (.04)	.25 (.05)	.24 (.05)
12 points	.41 (.04)	.52 (.05)	.59 (.05)	.53 (.05)	.23 (.05)	.36 (.05)	.31 (.05)	.33 (.06)

Note. Standard errors of the means are in parenthesis.

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Table 7

Fixed effects for multilevel regression model predicting paired associate recall for Block 4 in Experiment 2

Fixed Effects	**β**	***SE***	**Wald *z***	***p***
Intercept	**.28**	**.06**	**5.07**	**.001***
Age	**.24**	**.06**	**3.47**	**.001***
Value	**.05**	**.02**	**2.89**	**.01***
Gf	.02	.02	1.04	.30
Strategy Use	.22	.12	1.87	.06
Age × Value	−.03	.02	−1.39	.17
Age × GF	−.01	.02	−.57	.57
Age × Strategy Use	.09	.13	.7	.49
Value × Gf	**.01**	**.01**	**1.94**	**.05***
Value × Strategy Use	**.18**	**.06**	**2.95**	**.01***
Gf × Strategy Use	.02	.04	.58	.56
Age × Value × GF	−.01	.01	−1.44	.15
Age × Value × Strategy Use	**−.21**	**.07**	**−3.00**	**.01***
Age × Gf × Strategy Use	.00	.04	.01	.99
Value × Gf × Strategy Use	.05	.02	2.81	.01*
Age × Value × Gf × Strategy Use	**−.05**	**.01**	**−2.36**	**.05***

Note. Analyses were conducted on only the final study-test block because participants only made strategy reports for this block. Gf = general fluid intelligence measured with Raven's Progressive Matrices. Strategy use reflects self-reports of effective strategy use. *SE* = Standard Error.

* denotes $p < .05$.