

Aging, Neuropsychology, and Cognition

A Journal on Normal and Dysfunctional Development

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/nanc20

Memory and automatic processing of valuable information in younger and older adults

Dillon H. Murphy, Kara M. Hoover, Alan D. Castel & Barbara J. Knowlton

To cite this article: Dillon H. Murphy, Kara M. Hoover, Alan D. Castel & Barbara J. Knowlton (29 May 2024): Memory and automatic processing of valuable information in younger and older adults, *Aging, Neuropsychology, and Cognition*, DOI: [10.1080/13825585.2024.2360226](https://doi.org/10.1080/13825585.2024.2360226)

To link to this article: <https://doi.org/10.1080/13825585.2024.2360226>



Published online: 29 May 2024.



Submit your article to this journal [↗](#)



View related articles [↗](#)



View Crossmark data [↗](#)



Memory and automatic processing of valuable information in younger and older adults

Dillon H. Murphy , Kara M. Hoover , Alan D. Castel  and Barbara J. Knowlton 

Department of Psychology, University of California, Los Angeles, CA, USA

ABSTRACT

People often engage in the selective remembering of valuable or important information, whether strategic and/or automatic. We examined potential age-related differences in the automatic processing of value during encoding on later remembering by presenting participants with words paired with point values (range: 1–10 twice or 1–20) to remember for a later test. On the first three lists, participants were told that they would receive the points associated with each word if they recalled it on the test (their goal was to maximize their score). On the last three lists, we told participants that all words were worth the same number of points if recalled on the tests, thus making the point value paired with each word meaningless. Results revealed that selective memory may be impaired in older adults using procedures with larger value ranges. Additionally, we demonstrated that the automatic effects of value may have a greater effect on younger adults relative to older adults, but there may be instances where older adults also exhibit these automatic effects. Finally, strategic and automatic processes may not be related within each learner, suggesting that these processes may rely on different cognitive mechanisms. This indicates that these processes could be underpinned by distinct cognitive mechanisms: strategic processes might engage higher-level cognitive operations like imagery, while automatic processes appear to be more perceptually driven.

ARTICLE HISTORY

Received 30 June 2023
Accepted 20 May 2024

KEYWORDS

Memory; aging; value-directed remembering; automatic processing; strategic processing

When we encounter information that we want to remember, we often prioritize memory for what is most important. In the laboratory, this ability is typically assessed via value-directed remembering procedures whereby learners are presented with words paired with point values counting toward their scores if recalled (e.g., Castel et al., 2002). Generally, learners prioritize the encoding (e.g., Cohen et al., 2017; Murphy et al., 2021) and retrieval (see Murphy & Castel, 2022c; Stefanidi et al., 2018) of high-value relative to low-value information (Castel, 2008), particularly after gaining task experience and realizing that the volume of items in the list is greater than their memory capacity, illustrating the need to be selective (e.g., McGillivray & Castel, 2011; see; Knowlton & Castel, 2022 for a review).

CONTACT Dillon H. Murphy  dmurphy8@ucla.edu  Department of Psychology, University of California, 6526 Pritzker Hall, 502 Portola Plaza, Los Angeles, CA 90095, USA

© 2024 Informa UK Limited, trading as Taylor & Francis Group

Prioritizing important information has many obvious benefits like avoiding the consequences of forgetting (see Murphy & Castel, 2020), and some forms of selective memory are preserved in older adults (Castel, 2008; Castel et al., 2002, 2012; Hargis & Castel, 2018; Hargis et al., 2019; McGillivray & Castel, 2011; Murphy & Castel, 2022b; Murphy et al., 2023; Swirsky & Spaniol, 2019; Whatley et al., 2021) despite the general cognitive impairments accompanying healthy aging (Hess, 2005; Park & Festini, 2017; Salthouse, 2010, 2019; Thomas & Gutchess, 2020). Specifically, older adults often employ compensatory memory mechanisms to offset certain forms of memory loss (Hertzog & Dunlosky, 1996), potentially suggesting that strategic memory processes are preserved or even enhanced in older adults. Thus, both younger and older adults can remember important information at the expense of low-value items, but there may be age-related differences in how this is achieved.

When we prioritize memory for valuable information, we likely strategically (and selectively) engage in effective encoding strategies (e.g., mental imagery, sentence generation) to help us later recall this information (Dunlosky, 1998; Hennessee et al., 2019; Hertzog et al., 2008). For example, if you are at your favorite restaurant and decide to order something different than what you usually order and it turns out to be delicious, you might “make a mental note” to order this item again. This “mental note” exemplifies the strategic encoding of valuable information, and people can learn to use more effective encoding strategies as they gain experience (Storm et al., 2016). People can also update their encoding strategies after observations of forgetting (Hertzog et al., 2008) to prevent the future forgetting of valuable information. Thus, there is both a metacognitive component (an awareness of the need to be selective; Murphy et al., 2021) and a strategic component (selectively engaging in effective encoding strategies for high-value items; Hennessee et al., 2019) to remember important information.

While strategically attending to and encoding valuable information can contribute to selective memory, the effects of value on memory can also be involuntary. Specifically, rewarding information tends to be more salient relative to low-value information, leading to greater memorability (Gruber et al., 2016; see; Schultz, 2015 for a review). Keeping with the restaurant example, you may remember a particularly delicious menu item without strategically encoding this information. Specifically, the high saliency of the delicious food can enhance memory for the event without the need to selectively engage in elaborative rehearsal for important information. Instances whereby valuable information is well-remembered without the learner having engaged in strategic processing exemplify more automatic effects of value on memory (see also Jennings & Jacoby, 1993; Knowlton & Castel, 2022; Robison & Unsworth, 2017).

The automatic effects of value or reward on memory may be attributable to prediction errors: differences between one’s expectations and reality (Braun et al., 2018; den Ouden et al., 2012). At your favorite restaurant, if you choose to order a new item from the menu (rather than your usual order which you like), there is a risk that you will not like this meal – the food could be worse than you expected (a prediction error). However, if the new item turns out to be more delicious than you expected (also a prediction error), your memory for this event will likely be strengthened (see Glimscher, 2011 for an investigation of the neural mechanisms of prediction error). Thus, the automatic memory enhancement for valuable information may depend on initial value expectations. Neurologically, this likely occurs due to dopamine activity that codes the incentive salience of stimuli

(Berridge & Robinson, 1998), attributing value to cues that predict reward and thus allowing such cues to be preferentially encoded and remembered.

Alternatively, high-value items may be more salient than low-value items, resulting in greater attention and consequently enhanced encoding processes. This attentional enhancement may occur involuntarily, independent of intentional motivation to differentially encode items based on their value. In this account, value does not directly drive encoding but rather facilitates the initial processing of high-value items relative to low-value items. Studies have shown that when participants are given an encoding task on every trial (e.g., generate an image or count the vowels), the effects of value on encoding are diminished or negligible (Hennessee et al., 2019). This suggests that automatic effects are not obligatory as they would typically continue to influence memory even with a structured encoding task in place. However, the attentional influence of value may manifest when attentional resources are more flexible and can fluctuate. Hence, the effectiveness of this process depends on the availability and variability of attentional resources, rather than being an inherent or compulsory aspect of memory encoding.

Strategic and involuntary/automatic effects of reward on memory likely do not function in isolation – both mechanisms likely contribute (Bijleveld et al., 2012). Specifically, value may have an initial, involuntary effect benefiting memory performance (automatic processing) with subsequent strategic encoding that further drives value effects. Previous work suggests that younger and older adults both engage in the strategic encoding of high-value items to accomplish task goals (and older adults may do this to a greater extent; see Schwartz et al., 2023), but it is currently unclear whether younger and older adults differentially exhibit automatic effects of value. In a broader sense, value-based memory is shaped by a blend of cognitive mechanisms – some potentially operating more automatically with hippocampal involvement – and metacognitive strategies, which include determining which items to prioritize, estimating memory capacity, and engaging in goal-oriented planning that involves the frontal lobe, and older adults may use these metacognitive strategies to maximize memory (Castel, 2024).

As discussed previously, processing may play a role in value-directed remembering via dopaminergic input from reward regions of the brain modulating hippocampal activity during learning, leading to the strengthening of memory for high-value information (Adcock et al., 2006; Gruber et al., 2016). However, as we age, the dopaminergic system generally deteriorates (Dreher et al., 2008; Hämmerer & Eppinger, 2012; Volkow et al., 1996), likely contributing to age-related cognitive decline (Bäckman et al., 2010) and reduced neurological responses to value (Cohen et al., 2016). Thus, prior research provides some evidence that age-related cognitive impairments may hinder older adults' ability to engage in the automatic processing of rewarding information.

This is supported by some behavioral work disentangling the roles of automatic and strategic processing in younger and older adults (but see Mather & Schoeke, 2011). For example, Hennessee (2018) used a directed forgetting procedure where younger and older adult participants were shown words paired with point values that they would earn if they later correctly recognized the associated words. Importantly, after each word-point pair was shown, the participants were given a cue to “learn” or “forget” that word. To optimize their chance to earn the most points, participants should forego memory for the high-value items that they are told to forget and thus not engage in strategic processing of such items. They found that the young adult participants recognized the high-value

words significantly more often than the low-value words even for the words they were initially instructed to forget; however, the older adult participants did not exhibit this effect. Hennessee (2018) concluded that value-directed remembering may engage different mechanisms across the lifespan such that older adults engage in less involuntary processing of value than younger adults (see also Hennessee et al., 2024).

Some limitations to the study by Hennessee (2018) illustrate the need for further research on this topic. For example, there was a rather small sample size of older adults, which could explain why the older adults' recognition did not seem very sensitive to value regardless of whether the cue was "learn" or "forget," which deviates from prior work that has found that incidental memory for high-value information is preserved in older adults (Mather & Schoeke, 2011; Spaniol et al., 2014). Additionally, the directed-forgetting paradigm may have caused older adults to focus too much on the cue ("learn" or "forget"), resulting in insufficient allocation of attention to the point values paired with the words. Altogether, these limitations suggest that more research is needed before we can make a definitive conclusion about any age-related differences in value-directed automatic processing. Thus, to build upon Hennessee (2018) and to further disentangle the roles of strategic and automatic processes in value-directed remembering, the current study will examine recall, which prior work has found to have bigger effects of value than recognition (Castel, 2008; Elliott et al., 2019; Hennessee et al., 2019), via a new paradigm.

The current study

To examine potential age-related differences in the automatic effects of value, we developed a paradigm where we presented participants with lists of words paired with point values, and on the first few lists, participants were told that these point values counted toward their score if recalled, thus encouraging strategic and/or automatic processing of words paired with high point values. However, on later lists, participants were told that all words were of equal value regardless of the number presented with each word. These instructions should make the previous benefits of strategically processing the high-value words obsolete, suggesting that any sensitivity to value in the last three lists may be attributable to automatic processing. Critically, with this paradigm, we sought to compare younger and older adults' memorial selectivity for the high-value items in the first three lists as well as their selectivity in the last three lists to uncover any age-related differences in the usage of automatic processing from more strategic processes. We hypothesized that on the lists where the point values were no longer meaningful, older adults would be less sensitive to the presented point values than younger adults due to potential age-related impairments in the unintentional encoding of high-value words.

In the present work, we consider strategic and automatic processing as intentional and unintentional forms of encoding, respectively. Specifically, strategic processing refers to the deliberate allocation of cognitive resources toward high-value words. This intentional effort involves deploying effective encoding techniques – such as forming vivid mental images, creating associations, or embedding words in meaningful sentences – to enhance recall of high-value items on the first three lists. Conversely, automatic processing characterizes the latter three lists where point values presented alongside words are declared irrelevant. Despite this shift, participants might still exhibit a residual sensitivity to these previously emphasized values, an effect we interpret as unintentional/automatic.

In this stage, the influence of point values on memory encoding may operate involuntarily, reflecting an ingrained response to the value cues established in the earlier lists. We note that we use the term automaticity in a manner that is consistent with prior research on memory and aging (e.g., Jennings & Jacoby, 1993; Knowlton & Castel, 2022). Our approach is also consistent with Moors and De Houwer (2006) who argue that an automatic process should be defined in relation to a different process in terms of specific features. Here, we contrast the preferential encoding of high-value items when points contribute to the participant's score (strategic and goal-directed) and when they do not (involuntary and not goal-directed).

Experiment 1a

In Experiment 1a, younger and older adults studied six lists of words with each list containing 20 words. On each list, each word was paired with a point value ranging from 1 to 20. On the first three lists, participants were told that the point value associated with each word counted toward their score if recalled. However, on the last three lists, participants were told that all words were worth the same value. Specifically, we instructed participants that all words were worth 10 points and that the point values presented with each word no longer reflected the word's value and were meaningless (the point values paired with each word still ranged from 1 to 20). Participants' goal on all lists was to maximize their scores.

On Lists 1–3, compared with younger adults, we expected selectivity to be preserved in older adults, consistent with prior work demonstrating that older adults can engage in strategic processing by selectively allocating their more limited memorial resources toward high-value information (e.g., Castel et al., 2002; see; Knowlton & Castel, 2022 for a review). On Lists 4–6, although some work has found automaticity to be similar between younger and older adults (see Jennings & Jacoby, 1993), we expected younger adults to be more sensitive to the presented point values compared with older adults due to larger carry-over effects from earlier lists that could be based on memory for what the value means in terms of directing attention and reward-processing.

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 (IRB#12–000617 Memory, Attention, Emotion and Aging).

Participants

After exclusions, younger adults ($n = 56$; $M_{age} = 20.00$, $SD_{age} = 1.39$; 49 female, 7 male; 1 American Indian/Alaskan Native, 24 Asian/Pacific Islander, 1 Black, 10 Hispanic, 17 White, 3 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 (as was the case in each experiment). Older adults ($n = 55$; $M_{age} = 73.00$, $SD_{age} = 5.69$; 32 female, 23 male; 6 Black, 48 White, 1 other/unknown) were recruited from Amazon's Cloud Research (Chandler et al., 2019), a website that allows users to complete small tasks for pay. Cloud Research ensures that our study was only available to participants meeting our age requirement for older adults (aged 60+). Specifically, if someone does not meet that criterion, our study would not appear as an option for them to complete.

In each experiment, 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 had cheated). This exclusion process resulted in one exclusion from the younger adult group and 11 exclusions from the older adult group. In each experiment, we aimed to collect around 50 younger adults and 50 older adults. This sample size was based on some of our prior work using a similar design (e.g., Murphy & Knowlton, 2022), prior exploratory research, and the expectation of detecting a medium effect size. A sensitivity analysis indicated that, with this sample size, assuming $\alpha = .05$, we had an 80% chance of detecting a *medium* (Cohen's $d = .54$) difference between younger and older adults.

Materials and procedure

Participants were told that they would be presented with six lists of to-be-remembered words with each list containing 20 words. On each list, each word was paired with a unique, randomly assigned value between 1 and 20 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 500 ms inter-stimulus interval (blank screen). 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), words ranged from 5.48–12.65 and averaged 8.81 ($SD = 1.57$). In terms of concreteness (with lower values indicating lower concreteness), words ranged from 2.50–5.00 and averaged 4.52 ($SD = .46$). Frequency and concreteness ratings were generated using the English Lexicon Project website (Balota et al., 2007).

On the first three lists, participants were told that the point value associated with each word counted toward their score if recalled. However, on the last three lists, participants were told that all words were worth the same value. Specifically, all words were worth 10 points, and the point values presented with each word no longer reflected the word's value and were meaningless (the point values paired with each word still ranged from 1 to 20). Participants' goal on all lists was to maximize their scores. After the presentation of all 20 word-number pairs in each list, participants were given a self-paced free recall test (but were required to spend at least 30 seconds on each 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.

Results

To examine memory performance, 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 on Lists 1–3 when the presented point values counted toward participants' scores if recalled (see Figure 1(a)), 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 [$e^B = 1.07$, $CI_{95\%} = 1.06$ – 1.08 , $z = 13.09$, $p < .001$] such that high-value words were better recalled than low-value words. However, there was not an effect of age [$e^B = 1.11$, $CI_{95\%} = .79$ – 1.57 , $z = .60$, $p = .547$] such that younger adults ($M = .41$, $SD = .16$) and older adults ($M = .39$, $SD = .21$) recalled a similar proportion of words. Value interacted with age [$e^B = 1.05$, $CI_{95\%} = 1.03$ – 1.07 , $z = 4.91$, $p < .001$] and an analysis of the simple effects indicated that younger adults were more selective [$e^B = 1.09$, $CI_{95\%} = 1.08$ – 1.11 , $z = 12.81$, $p < .001$] than older adults [$e^B = 1.04$, $CI_{95\%} = 1.03$ – 1.05 , $z = 5.76$, $p < .001$].

We conducted a similar model to examine memory on Lists 4–6 when participants were told that all words were worth the same value (see Figure 1(b)). Results revealed that value significantly predicted recall [$e^B = 1.01$, $CI_{95\%} = 1.00$ – 1.02 , $z = 2.35$, $p = .019$] such that high-value words were better recalled than low-value words. However, there was not an effect of age [$e^B = .81$, $CI_{95\%} = .50$ – 1.31 , $z = -.86$, $p = .390$] such that younger adults ($M = .44$, $SD = .19$) and older adults ($M = .47$, $SD = .29$) recalled a similar proportion of words. Value did not interact with age [$e^B = 1.00$, $CI_{95\%} = .98$ – 1.02 , $z = .33$, $p = .744$] but an analysis of the simple effects provides some evidence that younger adults' recall was influenced by the presented values [$e^B = 1.01$, $CI_{95\%} = 1.00$ – 1.03 , $z = 2.00$, $p = .045$] whereas older adults' recall was not [$e^B = 1.01$, $CI_{95\%} = 1.00$ – 1.02 , $z = 1.37$, $p = .172$].

We also examined the within-subject relation between memory selectivity on the first three lists and the last three lists in younger and older adults. Specifically, using selectivity index scores to summarize the tendency to prioritize high-value items with a single value (see Castel et al., 2002 for more information), we used a General Linear Model to predict selectivity scores on Lists 4–6 using selectivity scores on Lists 1–3 as well as age group. Results revealed that selectivity on the lists with value-directed remembering instructions (i.e., Lists 1–3) did not predict selectivity on the lists where participants were told that all words were worth the same value (i.e., Lists 4–6), [$t(105) = 1.79$, $p = .076$, $\beta = .18$]. Additionally, there was not an effect of age [$t(105) = -.61$, $p = .544$, $\beta = -.12$] or an interaction between selectivity on Lists 1–3 and age [$t(105) = .35$, $p = .727$, $\beta = .07$]. This provides some evidence that successfully engaging in value-directed remembering via strategic and/or automatic processing when value-directed remembering was beneficial did not predict automatic processing engagement when value-directed remembering is not necessary.

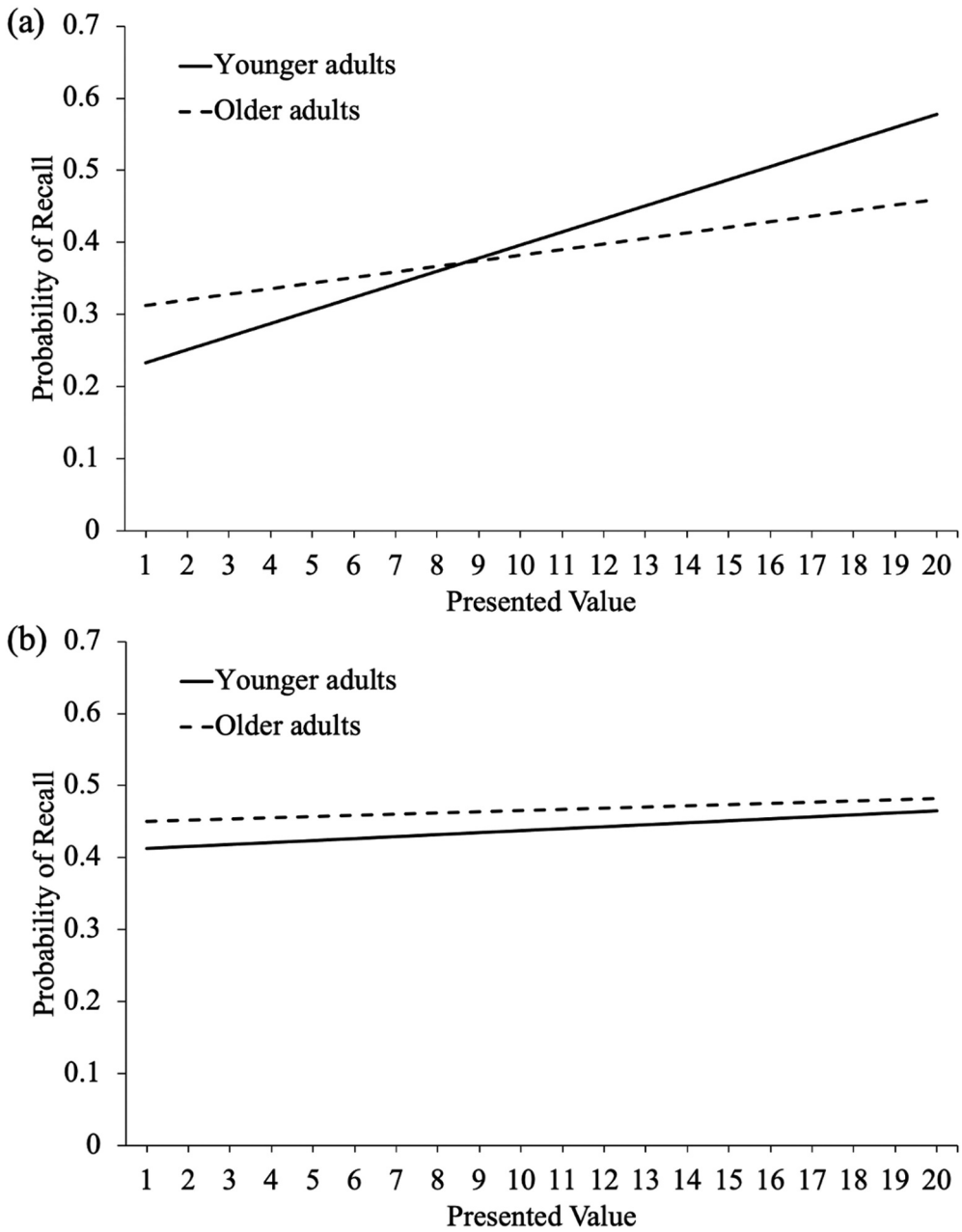


Figure 1. Linear trendlines for the probability of recall as a function of the presented point value for younger and older adults on Lists 1–3 (a) and Lists 4–6 (b) in Experiment 1a.

Discussion

In Experiment 1a, we did not observe age-related differences in total recall on either set of lists (as is typically seen in prior work, see Balota et al., 2000). However, an examination of the average time spent on the self-paced free recall tests indicated that older adults ($M =$

84.00 seconds, $SD = 72.87$) spent more time recalling words than younger adults ($M = 50.80$ seconds, $SD = 20.90$), [$t(109) = 3.28$, $p = .001$, $d = .62$] which could account for the lack of age-related differences in recall. In terms of prioritizing high-value items, contrary to prior work (e.g., Castel et al., 2002; Knowlton & Castel, 2022), younger adults were more selective than older adults on the first three lists when participants were told that they would receive the point value presented with each word if they recalled it on the test. However, on the last three lists, when participants were told that all words were worth the same value regardless of the value presented during the study phase, there was some evidence that younger adults' recall was more influenced than older adults' recall by the presented point values (as indicated by the simple effects analysis), but the interaction was not significant. Given that some of these findings contrast with prior findings, in Experiment 1b, we attempted to further explore these effects.

Experiment 1b

In Experiment 1a, younger adults did not recall more words than older adults. This is inconsistent with most memory research involving older adults tested in the laboratory (see Balota et al., 2000), although this may be attributable to older adults spending more time on each recall test. However, we also failed to demonstrate preserved memory selectivity in older adults. That is, in prior research, older adults displayed a similar tendency to recall high-value words better than low-value words compared with younger adults (see Knowlton & Castel, 2022). One potential explanation is that older adults may have been using external memory aids during the study (testing participants remotely may have enabled this form of "cheating").

Although we asked participants not to use any external aids and thus to use only their own memory to complete the study, the rate of self-reported cheating was much higher for older adults (17%) than younger adults (2%) in Experiment 1a. Thus, it is possible that many older adults felt the need to write words down but did not admit to doing so at the end of the task. While it is a good strategy to offload important information (Murphy, 2023b; Murphy & Castel, 2023a), we were interested in situations in which people had to rely on their own memory. As such, in Experiment 1b, we aimed to replicate the effects observed in Experiment 1a while adding more precautions to prevent cheating – we wanted to make it clear that participants should not use external aids to help them remember valuable information (and these additional precautions were employed in all subsequent experiments).

Method

Participants

After exclusions, younger adults ($n = 51$; $M_{age} = 20.45$, $SD_{age} = 1.86$; 39 female, 12 male; 1 American Indian/Alaskan Native, 25 Asian/Pacific Islander, 1 Black, 10 Hispanic, 11 White, 3 other/unknown) were recruited from the UCLA Human Subjects Pool. Older adults ($n = 46$; $M_{age} = 74.13$, $SD_{age} = 5.63$; 27 female, 19 male; 1 Black, 45 White) were recruited from Amazon's Cloud Research. No younger adults were excluded for cheating but there were three exclusions from the older adult group. We also excluded participants who did not select "Yes" when asked if they attested that they would not cheat and that they would

give their best effort. This exclusion process resulted in zero exclusions from the younger adult group and one exclusion from the older adult group. A sensitivity analysis indicated that, with this sample size, assuming $\alpha = .05$, we had an 80% chance of detecting a *medium* (Cohen's $d = .55$) difference between younger and older adults.

Materials and procedure

The task in Experiment 1b was the same as the task used in Experiment 1a except that we added additional instructions asking participants not to “cheat.” Specifically, as was done in Experiment 1a, the first instruction that participants received was “Please give your full effort on this task! PLEASE do not use any external aids and thus use ONLY YOUR OWN memory to complete the study.” Additionally, after reading instructions regarding the memory task, we told participants: “This task will be very difficult. We do not expect you to remember everything; you will likely only be able to remember some of the information. Please do not cheat by taking pictures of the screen, writing things down, or using any other aid to complete this task.” Finally, we told participants: “Again, we kindly ask that you do not cheat on this task by using any memory aids and that you give your full effort on this task. Do you attest that you will not cheat and that you will give your best effort?.” Participants then selected yes or no. These anti-cheating instructions (and exclusion criteria) were used in all subsequent experiments.

Results

First, to examine whether the precautions to reduce cheating in Experiment 1b were effective, we conducted a cross-experiment comparison on total recall. A 2 (Experiment 1a vs Experiment 1b) \times 2 (younger adults vs older adults) revealed that total recall was greater in Experiment 1a ($M = .42$, $SD = .21$) than in Experiment 1b ($M = .36$, $SD = .18$), [$F(1, 204) = 5.45$, $p = .021$, $\eta^2 = .03$]. However, there was not an effect of age [$F(1, 204) = .71$, $p = .399$, $\eta^2 < .01$], and there was not an interaction between experiment and age group [$F(1, 204) = .98$, $p = .324$, $\eta^2 = .01$]. Thus, while there may have been less cheating in Experiment 1b, this did not systematically differ as a function of age group.

To examine memory on Lists 1–3 when the presented point values counted toward participants' scores if recalled (see Figure 2(a)), 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 [$e^B = 1.06$, $CI_{95\%} = 1.05$ – 1.07 , $z = 11.64$, $p < .001$] such that high-value words were better recalled than low-value words. However, there was not an effect of age [$e^B = 1.30$, $CI_{95\%} = .91$ – 1.85 , $z = 1.43$, $p = .152$] such that younger adults ($M = .38$, $SD = .11$) and older adults ($M = .33$, $SD = .22$)¹ recalled a similar proportion of words. Value interacted with age [$e^B = 1.05$, $CI_{95\%} = 1.02$ – 1.07 , $z = 4.28$, $p < .001$] and an analysis of the simple effects indicated that younger adults were more selective [$e^B = 1.09$, $CI_{95\%} = 1.07$ – 1.10 , $z = 12.01$, $p < .001$] than older adults [$e^B = 1.04$, $CI_{95\%} = 1.02$ – 1.06 , $z = 4.92$, $p < .001$].

We conducted a similar model to examine memory on Lists 4–6 when participants were told that all words were worth the same value (see Figure 2(b)). Results revealed that value significantly predicted recall [$e^B = 1.01$, $CI_{95\%} = 1.00$ – 1.02 , $z = 2.33$, $p = .020$] such that high-value words were better recalled than low-value words. However, there was not an effect of age [$e^B = 1.20$, $CI_{95\%} = .80$ – 1.81 , $z = .87$, $p = .386$] such that younger adults (M

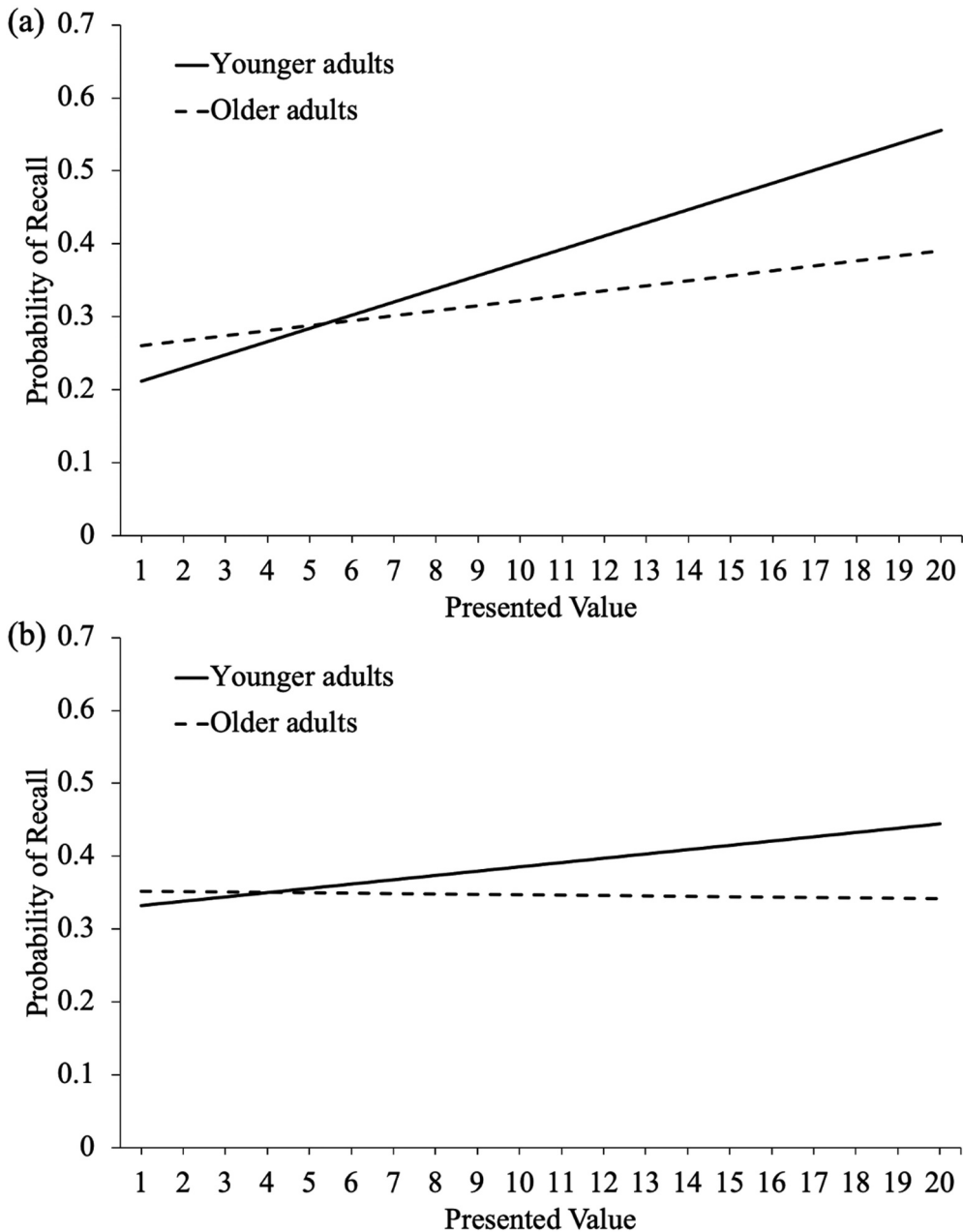


Figure 2. Linear trendlines for the probability of recall as a function of the presented point value for younger and older adults on Lists 1–3 (a) and Lists 4–6 (b) in Experiment 1b.

$= .39$, $SD = .15$) and older adults ($M = .35$, $SD = .25$) recalled a similar proportion of words. Value interacted with age [$e^B = 1.03$, $CI_{95\%} = 1.01-1.05$, $z = 2.94$, $p = .003$] and an analysis of the simple effects indicated that younger adults' recall was influenced by the presented values [$e^B = 1.03$, $CI_{95\%} = 1.01-1.04$, $z = 4.05$, $p < .001$] but older adults' recall was not [$e^B = 1.00$, $CI_{95\%} = .98-1.01$, $z = -.40$, $p = .690$].

We again used a General Linear Model to predict selectivity scores on Lists 4–6 using selectivity scores on Lists 1–3 as well as age group. Results revealed that selectivity on the lists with value-directed remembering instructions did not predict selectivity on the lists where participants were told that all words were worth the same value [$t(92) = -.22$, $p = .824$, $\beta = -.02$]. However, there was an effect of age [$t(92) = 2.20$, $p = .030$, $\beta = .46$] such that younger adults were more selective on Lists 4–6 than older adults, but there was not an interaction between age and list set (1–3 vs. 4–6) on selectivity [$t(92) = -.02$, $p = .981$, $\beta = -.01$].

Discussion

In Experiment 1b, on Lists 1–3 where participants were told the values paired with words counted toward their score, younger adults were more selective than older adults, but there was not a significant overall recall advantage for younger adults. Additionally, on Lists 4–6 when participants were told that the words were all the same value regardless of the point value presented with them, younger adults' recall – but not older adults' recall – was sensitive to the assigned value even though this value was not rewarded during the recall test. Thus, the results of Experiment 1b replicated Experiment 1a, even when greater precautions were taken to try to mitigate participants' usage of external aids during the task.

Experiment 2a

In Experiment 1, we found that younger adults showed a greater degree of selectivity than older adults which is inconsistent with prior work (Knowlton & Castel, 2022). However, using such a large range of values (1–20) compared with prior work using a smaller range (e.g., 1–12, see Castel et al., 2002; or 1–10 with values repeating twice, see; Middlebrooks et al., 2017) may have influenced selective memory processes. Additionally, prior work has shown that the point value scheme in value-directed remembering tasks can impact measures of selectivity (see Murphy, 2023a). As such, the value structure in Experiment 1 may have hindered strategic and/or automatic processing in older adults leading to decreased selectivity when the point values mattered and no selectivity when the presented values were arbitrary. A more restricted value structure (i.e., values 1 through 10) may facilitate the strategic and automatic enhancement of high-value items to a greater degree than the more expansive value structure in Experiment 1. Thus, although Experiment 1's findings may indicate that the strategic and automatic effects of value are stronger in younger adults than older adults, it is important to test whether there are age-related differences in the potential influence of the type of value structure on memory selectivity as there may be differences in younger and older adults' ability to execute a goal-based agenda in a (potentially) more complicated task and whether older adults' cognitive deficits affect memory for valuable information.

As such, in Experiment 2a, we investigated potential differences in memory selectivity between younger and older adults using varying value ranges within a list (i.e., small range: 1 to 10 versus large range: 1 to 20). We hypothesized that participants, especially older adults, would exhibit greater memory selectivity when the value range is smaller, as seen in prior work (e.g., Middlebrooks et al., 2017), due to their typically reduced cognitive

resources and processing efficiency (Hess, 2005; Park & Festini, 2017; Salthouse, 2010, 2019; Thomas & Gutchess, 2020). Specifically, a narrower range of values (e.g., 1–10) may simplify the task, reducing cognitive load and making it easier for older adults to discriminate between high and low-value items. This simpler structure also aligns better with older adults' tendency to rely on gist-based processing (e.g., Castel, 2005), allowing them to focus on the general importance of items without being overwhelmed by the details of a more extensive and complex range of values. Additionally, it is possible that a more familiar and constrained reward structure (1–10), with multiple words paired with each value, could provide more environmental support informing learners' metacognition and goals (see Craik, 2022), aiding older adults in prioritizing relevant information given their limited cognitive resources. Critically, such a finding would suggest that the value structure in Experiment 1 impeded older adults' ability to engage in strategic and automatic processing, bringing up the possibility that under the right conditions, older adults may engage in strategic and automatic processing of value to a similar degree as younger adults.

Method

Participants

Younger adults ($n = 113$; $M_{age} = 20.18$, $SD_{age} = 1.55$; 74 female, 38 male, 1 other; 41 Asian/Pacific Islander, 7 Black, 29 Hispanic, 28 White, 8 other/unknown) were recruited from the UCLA Human Subjects Pool. Older adults ($n = 110$; $M_{age} = 71.56$, $SD_{age} = 5.74$; 62 female, 48 male; 1 American Indian/Alaskan Native, 3 Black, 104 White, 2 other/unknown) were recruited from Amazon's Cloud Research (Chandler et al., 2019). Two younger adults and one older adult were excluded for admitting to cheating. Given that older adults typically perform worse on memory tasks than younger adults but this was not observed in Experiment 1, we doubled the sample size in Experiment 2 to enhance the robustness of our findings. A sensitivity analysis indicated that, with this sample size, assuming $\alpha = .05$, we had an 80% chance of detecting a *medium* (Cohen's $d = .38$) difference between younger and older adults.

Materials and procedure

The task in Experiment 2a was similar to that in Experiment 1. However, on all six lists, participants were told that they would score points for recalling words on the test and that they should try to maximize their scores (akin to Lists 1–3 in Experiment 1). For some participants ($n_{young} = 56$; $n_{old} = 56$), the point values ranged from 1 to 20 with each point value being used only once within each list. For other participants ($n_{young} = 57$; $n_{old} = 54$), the point values ranged from 1 to 10 with each point value being used twice within each list.

Results and discussion

To examine memory selectivity (see Figure 3), we conducted a logistic MLM with item-level recall modeled as a function of value and list (as continuous variables; list was included to examine potential changes as learners gain task experience) with age (young, old) and value structure (1 to 10 \times 2, 1 to 20) as between-subjects factors. The results of

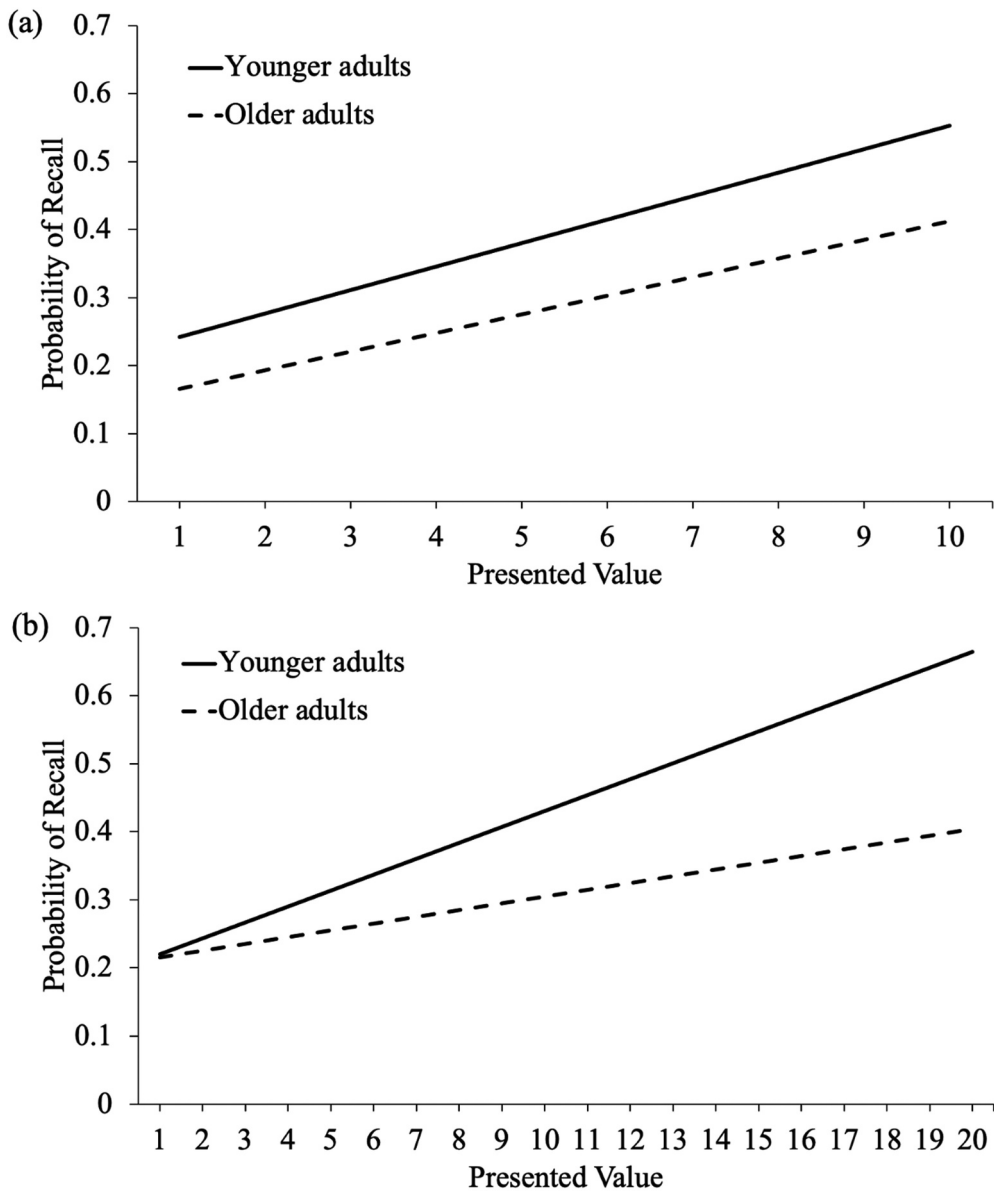


Figure 3. Linear trendlines for the probability of recall as a function of the presented point value for younger and older adults when point values ranged from 1 to 10 (a) and 1 to 20 (b) in Experiment 2a.

the model are shown in [Table 1](#). To highlight the main findings, high-value words were better recalled than low-value words and younger adults recalled more words than older adults. Additionally, the range of values also influenced recall, with better selectivity when the values ranged from 1 to 10 compared to 1 to 20. There was also an effect of list such that participants recalled more words on later lists.

The interaction between value and age indicated that younger adults were more selective than older adults, but this was dependent on the value structure.

Table 1. Results of a multi-level model with value, list, age group, and value structure predicting recall accuracy in Experiment 2a. Note: YA = younger adults, OA = older adults.

Variable	Effect	Estimate	SE	exp(B)	95% exp(B) Confidence Interval		z	p
					Lower	Upper		
(Intercept)	(Intercept)	-0.58	0.06	0.56	0.5	0.63	-9.49	<.001
Presented Value	Presented Value	0.12	0	1.13	1.12	1.14	30.84	<.001
Age Group	YA – OA	0.57	0.12	1.76	1.39	2.24	4.64	<.001
Value Structure	1–10 × 2–1 to 20	0.47	0.12	1.59	1.25	2.02	3.81	<.001
List	List	0.04	0.01	1.05	1.03	1.07	4.49	<.001
Age Group1 * Value Structure	YA – OA * 1–10 × 2–1 to 20	0.09	0.24	1.09	0.68	1.77	0.37	0.711
Presented Value * Age Group	Presented Value * YA – OA	0.04	0.01	1.04	1.03	1.06	5.06	<.001
Presented Value * Value Structure	Presented Value * 1–10 × 2– 1 to 20	0.08	0.01	1.08	1.07	1.1	10.09	<.001
Age Group * List	YA – OA * List	-0.02	0.02	0.98	0.95	1.02	-0.88	0.38
Value Structure * List	1–10 × 2–1 to 20 * List	0.04	0.02	1.05	1.01	1.09	2.24	0.025
Presented Value * List	Presented Value * List	0.01	0	1.01	1	1.01	3.64	<.001
Presented Value * Age Group * Value Structure	Presented Value * YA – OA * 1–10 × 2–1 to 20	-0.03	0.02	0.97	0.94	1	-2.03	0.042
Age Group * Value Structure * List	YA – OA * 1–10 × 2–1 to 20 * List	-0.06	0.04	0.95	0.88	1.02	-1.4	0.162
Presented Value * Age Group * List	Presented Value * YA – OA * List	0	0	1	0.99	1.01	-0.51	0.611
Presented Value * Value Structure * List	Presented Value * 1–10 × 2– 1 to 20 * List	0.01	0	1.01	1	1.02	2.09	0.037
Presented Value * Age Group * Value Structure * List	Presented Value * YA – OA * 1–10 × 2–1 to 20 * List	0.01	0.01	1.01	0.99	1.03	1.33	0.183

Specifically, an analysis of the simple effects indicated that when the values ranged from 1 to 20, younger adults were more selective [$e^B = 1.12$, $CI_{95\%} = 1.11-1.13$, $z = 22.80$, $p < .001$] than older adults [$e^B = 1.06$, $CI_{95\%} = 1.05-1.07$, $z = 10.84$, $p < .001$] but when the values ranged from 1 to 10, younger adults were similarly selective [$e^B = 1.19$, $CI_{95\%} = 1.17-1.22$, $z = 17.88$, $p < .001$] as older adults [$e^B = 1.16$, $CI_{95\%} = 1.14-1.19$, $z = 14.48$, $p < .001$].

The interaction between value and value structure indicated that, across age groups, participants were more YA selective when the values ranged from 1–10 [$e^B = 1.18$, $CI_{95\%} = 1.16-1.20$, $z = 22.78$, $p < .001$] compared with 1–20 [$e^B = 1.09$, $CI_{95\%} = 1.08-1.09$, $z = 23.64$, $p < .001$], but this was dependent on task experience (this trend was more pronounced on later lists). In sum, Experiment 2a suggests that the value structure used in value-directed remembering tasks can influence how younger and older adults use value to guide memory, and that task experience may also play a role.

Experiment 2b

To examine the automatic effects of value with different value structures, in Experiment 2b we employed a procedure similar to that of Experiment 1 using the two different ranges of values from Experiment 2a. Specifically, after studying and being tested on three lists, participants in the last three lists were informed that the presented point values were no longer relevant. Similar to Experiment 2a, younger and older adults studied lists with values ranging either from 1 to 10 (repeating twice) or 1 to 20.

Method

Participants

Younger adults ($n = 111$; $M_{age} = 20.17$, $SD_{age} = 1.70$; 90 female, 18 male, 3 other; 49 Asian/Pacific Islander, 2 Black, 23 Hispanic, 30 White, 7 other/unknown) were recruited from the UCLA Human Subjects Pool. Older adults ($n = 108$; $M_{age} = 73.35$, $SD_{age} = 5.79$; 62 female, 46 male; 1 Asian/Pacific Islander, 4 Black, 103 White) were recruited from Amazon's Cloud Research (Chandler et al., 2019). One younger adult and one older adult were excluded for admitting to cheating. A sensitivity analysis indicated that, with this sample size, assuming $\alpha = .05$, we had an 80% chance of detecting a *medium* (Cohen's $d = .38$) difference between younger and older adults.

Materials and procedure

The materials and procedure were similar to Experiment 2a. However, like in Experiment 1, on the first three lists, participants were told that the point value associated with each word counted toward their score if recalled but on the last three lists, participants were told that all words were worth the same value. Specifically, all words were worth 1 point (we used 1 rather than 10 as it was the lowest value for both scoring structures; if we used 10, this would have been the high value for one list type and the middle value for the other, which could affect the results), and the point values presented with each word no longer reflected the word's value and were meaningless. Participants' goal on all lists was to maximize their score. For some participants ($n_{young} = 53$; $n_{old} = 51$), the point values ranged from 1 to 20 with each point value being used only once within each list for all six lists. For other participants ($n_{young} = 58$; $n_{old} = 57$), the point values ranged from 1 and 10 with each point value being used twice within each list.

Results

To examine memory on Lists 1–3 when the presented point values counted toward participants' scores if recalled (see Figure 4), we conducted a logistic MLM with item-level recall modeled as a function of value with age (young, old) and value structure (1 to 10 \times 2, 1 to 20) as between-subjects factors. Results revealed that value significantly predicted recall [$e^B = 1.10$, $CI_{95\%} = 1.09$ – 1.11 , $z = 18.09$, $p < .001$] such that high-value words were better recalled than low-value words. There was an effect of age [$e^B = 1.78$, $CI_{95\%} = 1.45$ – 2.17 , $z = 5.61$, $p < .001$] such that younger adults recalled a greater proportion of words ($M = .41$, $SD = .15$) than older adults ($M = .29$, $SD = .15$).² Value structure predicted recall [$e^B = 1.48$, $CI_{95\%} = 1.21$ – 1.81 , $z = 3.81$, $p < .001$] such that participants recalled a greater proportion of words when the values ranged from 1 to 20 ($M = .36$, $SD = .18$) than when the values ranged from 1 to 10 ($M = .34$, $SD = .15$). Value structure did not interact with age [$e^B = 1.01$, $CI_{95\%} = .68$ – 1.51 , $z = .05$, $p = .956$], value did not interact with age [$e^B = 1.01$, $CI_{95\%} = .99$ – 1.03 , $z = .76$, $p = .449$], but value interacted with value structure [$e^B = 1.06$, $CI_{95\%} = 1.04$ – 1.08 , $z = 5.26$, $p < .001$] such that participants were more selective when values ranged from 1 to 10 [$e^B = 1.13$, $CI_{95\%} = 1.11$ – 1.16 , $z = 13.21$, $p < .001$] than 1 to 20 [$e^B = 1.07$, $CI_{95\%} = 1.06$ – 1.08 , $z = 13.76$, $p < .001$]. The three-way interaction between value, age, and value structure was not significant [$e^B = .99$, $CI_{95\%} = .95$ – 1.04 , $z = -.32$, $p = .747$].

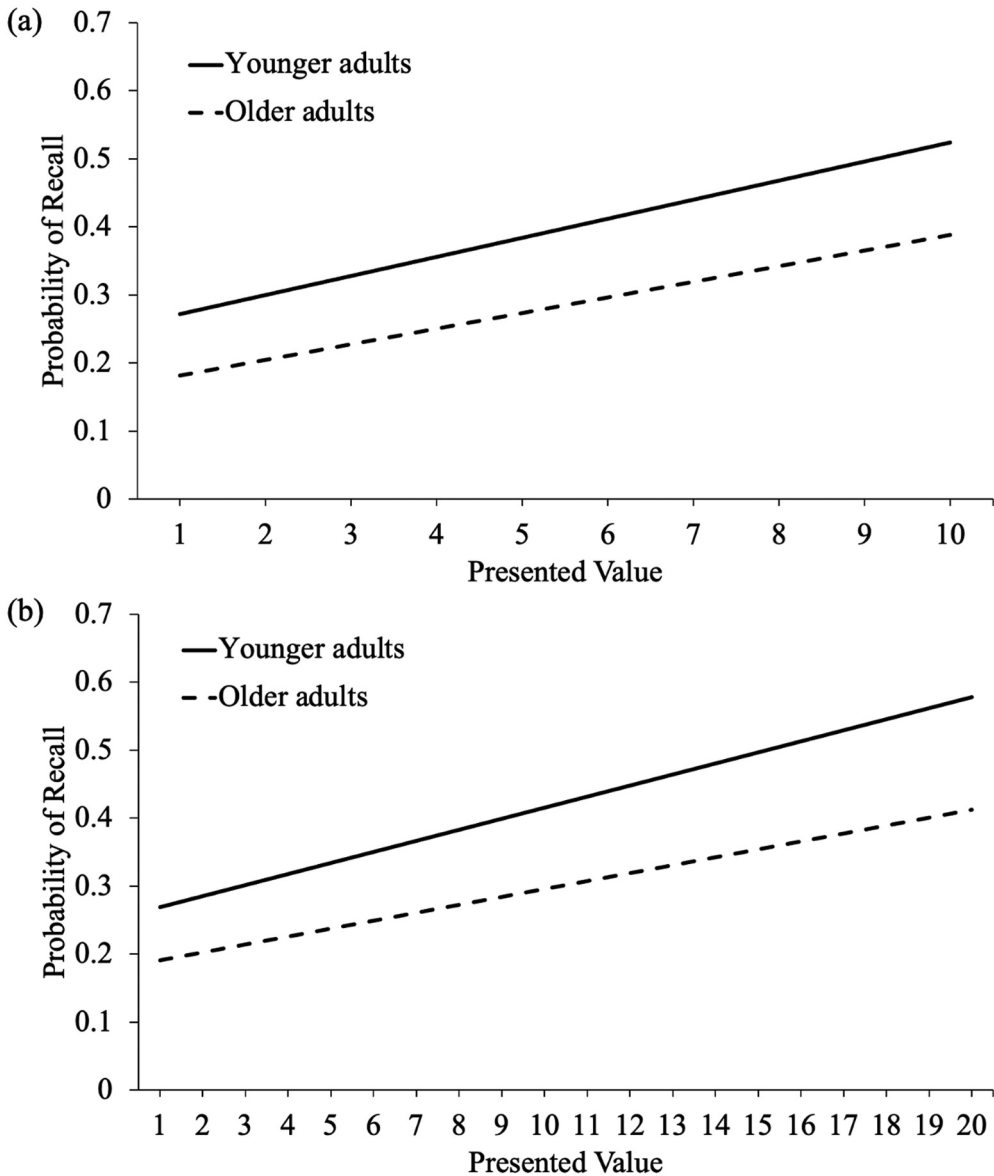


Figure 4. Linear trendlines for the probability of recall as a function of the presented point value for younger and older adults on Lists 1–3 when point values ranged from 1 to 10 (a) and 1 to 20 (b) in Experiment 2b.

We conducted a similar model to examine memory on Lists 4–6 when participants were told that all words were worth the same value (see Figure 5). Results revealed that value significantly predicted recall [$e^B = 1.02$, $CI_{95\%} = 1.01-1.03$, $z = 3.89$, $p < .001$] such that high-value words were better recalled than low-value words. There was an effect of age [$e^B = 1.45$, $CI_{95\%} = 1.13-1.87$, $z = 2.89$, $p = .004$] such that younger adults recalled a greater proportion of words ($M = .43$, $SD = .18$) than older adults ($M = .34$, $SD = .21$). Value structure did not predict recall [$e^B = .90$, $CI_{95\%} = .70-1.16$, $z = -.81$, $p = .416$] and

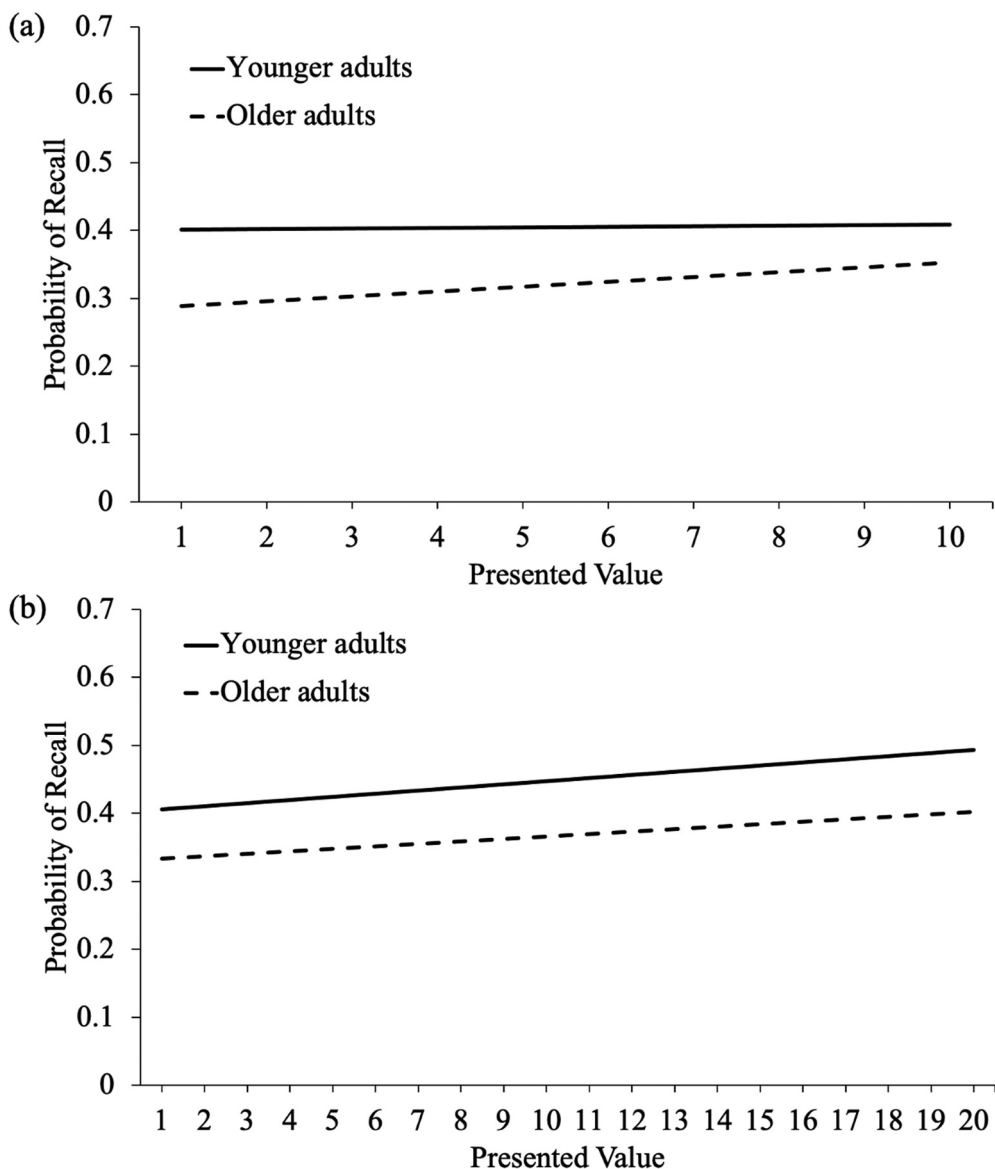


Figure 5. Linear trendlines for the probability of recall as a function of the presented point value for younger and older adults on Lists 4–6 when point values ranged from 1 to 10 (a) and 1 to 20 (b) in Experiment 2b.

value structure did not interact with age [$e^B = .97$, $CI_{95\%} = .59-1.61$, $z = -.11$, $p = .910$]. Value did not interact with age [$e^B = .98$, $CI_{95\%} = .96-1.00$, $z = -1.54$, $p = .124$] or value structure [$e^B = 1.00$, $CI_{95\%} = .98-1.02$, $z = .03$, $p = .973$]. The three-way interaction between value, age, and value structure did not reach significance [$e^B = .97$, $CI_{95\%} = .93-1.01$, $z = -1.67$, $p = .096$] but an analysis of the simple effects indicated that when the values ranged from 1 to 20, younger adults were similarly selective [$e^B = 1.02$, $CI_{95\%} = 1.01-1.03$, $z = 3.19$, $p = .001$] as older adults [$e^B = 1.02$, $CI_{95\%} = 1.01-1.03$, $z = 2.70$, $p = .007$] but

when the values ranged from 1 to 10, younger adults were not selective [$e^B = 1.00$, $CI_{95\%} = .98-1.03$, $z = .30$, $p = .768$] but value predicted memory for older adults [$e^B = 1.04$, $CI_{95\%} = 1.01-1.07$, $z = 2.76$, $p = .006$].

Finally, we again used a General Linear Model to predict selectivity scores on Lists 4–6 using selectivity scores on Lists 1–3 as well as age group and value structure. The only effect to reach significance was selectivity scores on Lists 1–3 predicting selectivity scores on Lists 4–6 [$t(210) = 2.21$, $p = .029$, $\beta = .15$].

Discussion

In Experiment 2b, on Lists 1–3, selectivity was similar in younger and older adults regardless of the value structure. On Lists 4–6 when learners were told that all words were worth the same value, younger and older adults showed similar levels of selectivity when values ranged from 1 to 20, but only older adults showed selectivity when values ranged from 1 to 10. Thus, the more automatic/less intentional effects of value in younger and older adults may only occur under certain conditions, although it is unclear how the range in value may influence age-related effects (see General Discussion for some possible reasons/speculation). It is possible that the repeated values and more restricted range may have facilitated automatic processing in older adults, creating a clearer goal in the task, which then carried over to subsequent lists possibly due to attentional focus on the limited values. However, it is also possible that younger adults were more flexible in changing their goals and strategies across the different lists due to enhanced cognitive control processes in younger adults (Lustig & Flegal, 2008), although future research is needed to test this in greater detail.

General discussion

In the present study, we were interested in potential age-related differences in the more automatic/less intentional effect of value on remembering as there may be dual processes that contribute to age-related differences in memory for rewarding information (Knowlton & Castel, 2022). To investigate this, we utilized a new paradigm that attempts to isolate more automatic processing from strategic processing. In this paradigm (used in Experiments 1 and 2b), participants were shown six lists of words paired with point values to remember for a later test. For the first three lists, the point values associated with the words contributed to participants' recall scores such that if they correctly recalled the words on a later test, they would gain the points that were paired with the presented word. Therefore, to optimize their scores, it would be beneficial for participants to prioritize memory for the highest-valued items. However, on the last three lists, the participants were told that the point values paired with the words were now meaningless such that each word was worth the same value if correctly recalled. Critically, compared to the first three lists, prioritizing the highest-valued items was no longer advantageous. Thus, if participants still showed effects of value on remembering in the latter three lists, this would suggest that participants were not being strategic (as the presented point values no longer matter) but instead were involuntarily prioritizing high-valued words. However, we acknowledge that some participants may have used the point values to

drive encoding if they still felt it may be relevant to goal-based memory, despite being instructed otherwise (we discuss this idea further later).

In Experiment 1, results revealed that on lists where the presented point values counted toward participants' scores if recalled (i.e., Lists 1–3), younger adults were more selective than older adults, contrary to prior work (Castel et al., 2002; Knowlton & Castel, 2022). Since some of this prior work used smaller value ranges (e.g., 1–12, see Castel et al., 2002) compared with Experiment 1 (1–20), the point value structure may be an unforeseen mediator of age-related differences in selective memory. For example, Murphy and Castel (2022a) presented younger adults from the UCLA Human Subjects Pool and older adults from Cloud Research (as was the case in the current study) with shorter lists of 12 words paired with point values 1–12 and demonstrated preserved selectivity in older adults (see also Murphy & Castel, 2023b). Thus, it is possible that presenting younger and older adults with lists of 20 words paired with point values 1–20 in Experiment 1 may have affected older adults' selectivity, which could be a potential reason why we found impaired selectivity in older adults relative to younger adults compared to prior work that has used more restricted value structures. However, future work is needed to test this more directly, possibly with other value-based materials that are not numerical and do not have a strict value scale (e.g., more subjective, such as different items that are relevant when packing for a trip; see Murphy & Castel, 2022b).

In alignment with this possibility, in Experiment 2a, we found that the point value structure might explain this discrepancy between the present study and prior work. Specifically, younger and older adults were similarly selective when studying words paired with values 1–10 but younger adults were more selective than older adults when the values ranged from 1–20. These results suggest that value structure plays an important role in selective memory, particularly in older adults. This may be because the complexity of processing and integrating information related to a wider range of less familiar values may overwhelm the cognitive resources of older adults, leading to reduced selectivity. Additionally, the distribution of values within the range could also have influenced the older adults' selectivity. For example, having two values of 10 as opposed to a single value of 20 may provide older adults greater clarity of what specific items are of higher value, which could aid in their selectivity. Thus, different perceptual and cognitive factors, such as task demands, processing capacity, and value discrimination, may all contribute to the observed effect of value structure on selectivity in older adults.

In terms of memory on later lists where the values were meaningless, the present study suggests that for both young and old learners, value-directed remembering experience may lead to involuntary enhancement of encoding for high-value items, even when all items are equally important to remember. This finding could also represent a residual effect of goal-independent automatic processes that rely on the value cue that was formerly indicative of reward but still carries over onto the later lists. In terms of age-related differences, the data suggest that the automatic effects of value are stronger in younger adults compared with older adults (Experiment 1), though there may be conditions where older adults also show these automatic effects (Experiment 2b).

Importantly, the effect of value structure on older adults' memorial selectivity may also affect their unintentional/automatic processing of high-value items. This could explain why, in Experiment 1, younger adults still showed an effect of value on the later lists despite the presented values being meaningless whereas the older adults did not.

Specifically, the value structure in Experiment 1 may have reduced involuntary value-directed processing in older adults, leading to decreased selectivity when the point values mattered and no selectivity when the presented values were arbitrary. With a more restricted value structure (i.e., values 1 through 10), involuntary enhancement of encoding of high-value items may be better facilitated in older adults than with the more expansive value structure in Experiment 1 as the more limited range may cater toward the smaller working memory span in older adults (Hasher & Zacks, 1988; Hayes et al., 2013). Relatedly, there is evidence that certain factors (e.g., font size) can unintentionally influence an item's perceived importance even when a value cue is present (see Luna et al., 2019; Murphy et al., 2024). This is consistent with the idea that factors that are unrelated to a learning goal can still influence memory. Thus, although Experiment 1's findings may indicate that the automatic effects of value are stronger in younger adults than older adults and carry over onto later lists, Experiment 2 illustrated the importance of considering value structure.

The current study also sought to begin disentangling the relationship between strategic and automatic processing in value-directed remembering. Some prior work suggests that both strategic and automatic effects likely contribute to selective memory (Bijleveld et al., 2012) such that high-value information has an initial, involuntary effect benefiting memory performance (automatic processing) that is later complemented by strategic processes. Thus, in our experiments, we examined whether a participant's tendency to strategically recall high- relative to low-value words on the first three lists predicts a similar pattern of memory selectivity on the last three lists. However, there was not a significant relation between selective memory on the first three lists and the last three lists in Experiment 1 (though there was a small relationship in Experiment 2b), potentially indicating that strategic processing is not highly related to automatic processing within individual learners, suggesting these processes may rely on different cognitive mechanisms (see also Knowlton & Castel, 2022).

Our assertion that strategic and automatic processes may rely on different mechanisms aligns with broader theories in cognitive psychology that distinguish between controlled or strategic processes and more automatic ones (see Jennings & Jacoby, 1993). By applying this dual-process framework to the domain of value-directed remembering, the present study suggests that a similar dichotomy influences how value affects memory. Thus, while there are various ways to consider the processes involved in this task, one broad distinction could be that there are cognitive processes that lead to more automatic/unintentional word encoding (that may be more hippocampal), but also more metacognitive processes that guide the decisions and goals one may implement to selectively remember higher value words, and decide how many words can be effectively remembered (guided by frontal lobe process), and older adults may use metacognitive awareness to focus on remembering higher value words (Castel, 2024). However, it is important to note that the current study does not explicitly identify the precise mechanisms that operate within the realm of value-directed remembering. The next steps in this line of research involve discerning the distinct mechanisms that drive strategic versus automatic processing, particularly in the specific context of assigning and recalling valued information.

In the latter phase of our experiments where the previously emphasized point values alongside items are declared irrelevant, participants often still prioritized high-value

words, albeit to a lesser degree compared to the initial lists. While we interpret this lingering attention to point values as evidence for the automatic or unintentional processing of high-value items, this effect could stem from suspicion – participants might wonder why point values are displayed if they are supposedly inconsequential. However, the feedback employed in the second set of lists solely focuses on total recall without highlighting individual point values. This feedback, coupled with explicit instructions that deemphasize the importance of point values, should likely remove any incentive for strategic prioritization based on value.

On the first three lists, participants likely engage in the strategic processing of high-value words (e.g., using mental imagery or other elaborative encoding strategies for the highest-valued words; see Cohen et al., 2017). However, when participants see a high-value word on the last three lists, there may be some carry-over effects that are consistent with what may be considered non-strategic, as we instructed participants that all words were equally valuable, and we offered feedback consistent with this such that they received 10 points for each word recalled regardless of the point paired with the word. This carry-over effect may reflect automatic processing such that when participants see a high value next to a word, this item briefly becomes more salient, leading to a small increase in the recallability of that item.

It is possible that younger participants, possibly more familiar with experimental environments, might exhibit heightened suspicion regarding the meaningless values on later lists. This could lead younger adults to continue prioritizing higher-value words in the latter part of the study, under the belief that these values could still hold significance despite receiving feedback on the recall tests that the points are no longer relevant. Such a variance in suspicion levels between younger and older adults could indeed impact the observed differences in responses to the value structures within our memory tasks. Another potential limitation of the present study is the impact of motivational differences between younger and older participants, such as the observed increased persistence in recall efforts among older adults. Future work could equalize incentives across age groups through financial reimbursement for performance or other forms of incentives to motivate effort and time on task. Future research could also benefit from analyzing recall latency or inter-response time to determine whether older adults continue to produce recall items later in the process compared to younger adults. This could provide further insights into age-related differences in memory retrieval dynamics.

Prior work has investigated how participants recall the point values associated with studied words. Specifically, Castel et al. (2007) demonstrated that participants generally have better recall for words associated with higher values and while both younger and older adults show proficiency in identifying words as high or low in value, older adults tend to grasp the general value (the gist) of high-valued words but are less precise in recalling specific numeric values compared to younger adults. Furthermore, older adults are more adept at recognizing, but not recalling, words associated with negative values. This underscores the variance in memory processing strategies across different age groups, with older adults relying more on gist-based encoding and retrieval. This gist-based processing may have manifested in the present study when the values were meaningless as older adults may still unintentionally capture the gist by better encoding information that might be important. Additionally, older adults' better performance with simpler value ranges suggests a preference for processing the general "gist" of information, rather than engaging with more complex, detailed value distinctions.

While the present experiments offer valuable insights into the processing of valuable information, especially among older adults, the online data collection method, despite its efficacy as shown in prior research from our lab, may have limitations in data quality compared to in-person collection. This could affect real-world applicability (see Greene & Naveh-Benjamin, 2022 for an overview of the potential advantages and disadvantages of online data collection; see Anwyl-Irvine et al., 2021 for an examination of the accuracy and precision of online data). Additionally, our online recruitment might have attracted a higher-functioning segment of older individuals. Future research should aim to include a more diverse population to ensure broader applicability of the findings.

In sum, we have provided some evidence that selective memory may be impaired in older adults using procedures with larger value ranges (in contrast to prior work, e.g., Castel et al., 2002; Knowlton & Castel, 2022). Additionally, we demonstrated that the automatic effects of value may have a greater effect on younger adults relative to older adults, but there may be instances where older adults also exhibit these automatic effects. Finally, strategic and automatic processes may not be related within each learner (or if they are related, the effect is small), suggesting that these processes may rely on different cognitive mechanisms. This indicates that these processes could be underpinned by distinct cognitive mechanisms: strategic processes might engage higher-level cognitive operations like imagery, while automatic processes appear to be more perceptually driven. Future research should investigate these mechanisms further in both younger and older adults, including those in the early stages of Alzheimer's disease (e.g., Castel et al., 2009). Such studies are essential to understand whether and how different cognitive operations are affected or preserved with the onset of dementia.

Notes

1. Again, an examination of the average time spent on the self-paced free recall tests indicated that older adults ($M = 64.70$ seconds, $SD = 35.50$) spent more time recalling words than younger adults ($M = 47.60$ seconds, $SD = 19.06$), [$t(95) = 3.00$, $p = .003$, $d = .61$], possibly explaining similar total recall across age groups.
2. There were still age-related differences in time spent recalling the words in both Experiment 2a and 2b [both $ps < .005$], with older adults spending longer than younger adults.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by the National Institutes of Health [National Institute on Aging; Award Number R01 AG044335 to Alan Castel]. The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. The experiments reported in this article were not formally preregistered, but the stimuli and data are available on the Open Science Framework https://osf.io/4bxjy/?view_only=5d7283ef70f14dbf8b7144ad3b4e51b6.

ORCID

Dillon H. Murphy  <http://orcid.org/0000-0002-5604-3494>

Kara M. Hoover  <http://orcid.org/0000-0001-8396-4734>

Alan D. Castel  <http://orcid.org/0000-0003-1965-8227>

Barbara J. Knowlton  <http://orcid.org/0000-0002-1532-5081>

References

- Adcock, R. A., Thangavel, A., Whitfield-Gabrieli, S., Knutson, B., & Gabrieli, J. D. (2006). Reward-motivated learning: Mesolimbic activation precedes memory formation. *Neuron*, 50(3), 507–517. <https://doi.org/10.1016/j.neuron.2006.03.036>
- Anwyl-Irvine, A., Dalmaijer, E. S., Hodges, N., & Evershed, J. K. (2021). Realistic precision and accuracy of online experiment platforms, web browsers, and devices. *Behavior Research Methods*, 53(4), 1407–1425. <https://doi.org/10.3758/s13428-020-01501-5>
- Bäckman, L., Lindenberger, U., Li, S. C., & Nyberg, L. (2010). Linking cognitive aging to alterations in dopamine neurotransmitter functioning: Recent data and future avenues. *Neuroscience & Biobehavioral Reviews*, 34(5), 670–677. <https://doi.org/10.1016/j.neubiorev.2009.12.008>
- Balota, D. A., Dolan, P. O., & Duchek, J. M. (2000). Memory changes in healthy young and older adults. *The Oxford Handbook of Memory*, 395–410.
- Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., Neely, J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). The English lexicon project. *Behavior Research Methods*, 39(3), 445–459. <https://doi.org/10.3758/BF03193014>
- Berridge, K. C., & Robinson, T. E. (1998). What is the role of dopamine in reward: Hedonic impact, reward learning, or incentive salience? *Brain Research Reviews*, 28(3), 309–369. [https://doi.org/10.1016/S0165-0173\(98\)00019-8](https://doi.org/10.1016/S0165-0173(98)00019-8)
- Bijleveld, E., Custers, R., & Aarts, H. (2012). Adaptive reward pursuit: How effort requirements affect unconscious reward responses and conscious reward decisions. *Journal of Experimental Psychology: General*, 141(4), 728–742. <https://doi.org/10.1037/a0027615>
- Braun, E. K., Wimmer, G. E., & Shohamy, D. (2018). Retroactive and graded prioritization of memory by reward. *Nature Communications*, 9(1), 4886. <https://doi.org/10.1038/s41467-018-07280-0>
- Castel, A. D. (2005). Memory for grocery prices in younger and older adults: The role of schematic support. *Psychology and Aging*, 20(4), 718–721. <https://doi.org/10.1037/0882-7974.20.4.718>
- Castel, A. D. (2008). The adaptive and strategic use of memory by older adults: Evaluative processing and value-directed remembering. In A. S. Benjamin & B. H. Ross (Eds.), *The psychology of learning and motivation* (Vol. 48, pp. 225–270). Academic Press.
- Castel, A. D. (2024). Memory selectivity in older age. *Current Opinion in Psychology*, 55, 101744. <https://doi.org/10.1016/j.copsyc.2023.101744>
- Castel, A. D., Balota, D. A., & McCabe, D. P. (2009). Memory efficiency and the strategic control of attention at encoding: Impairments of value-directed remembering in Alzheimer’s disease. *Neuropsychology*, 23(3), 297–306. <https://doi.org/10.1037/a0014888>
- Castel, A. D., Benjamin, A. S., Craik, F. I. M., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. *Memory & Cognition*, 30(7), 1078–1085. <https://doi.org/10.3758/BF03194325>
- Castel, A. D., Farb, N., & Craik, F. I. M. (2007). Memory for general and specific value information in younger and older adults: Measuring the limits of strategic control. *Memory & Cognition*, 35(4), 689–700. <https://doi.org/10.3758/BF03193307>
- Castel, A. D., McGillivray, S., & Friedman, M. C. (2012). Metamemory and memory efficiency in older adults: Learning about the benefits of priority processing and value-directed remembering. In M. Naveh-Benjamin & N. Ohta (Eds.), *Memory and aging: Current issues and future directions* (pp. 245–270). Psychology Press.

- Chandler, J., Rosenzweig, C., Moss, A. J., Robinson, J., & Litman, L. (2019). Online panels in social science research: Expanding sampling methods beyond mechanical Turk. *Behavior Research Methods*, 51(5), 2022–2038. <https://doi.org/10.3758/s13428-019-01273-7>
- Cohen, M. S., Rissman, J., Hovhannisyann, M., Castel, A. D., & Knowlton, B. J. (2017). Free recall test experience potentiates strategy-driven effects of value on memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 43(10), 1581–1601. <https://doi.org/10.1037/xlm0000395>
- Cohen, M. S., Rissman, J., Suthana, N. A., Castel, A. D., & Knowlton, B. J. (2016). Effects of aging on value-directed modulation of semantic network activity during verbal learning. *Neuroimage: Reports*, 125, 1046–1062. <https://doi.org/10.1016/j.neuroimage.2015.07.079>
- Craik, F. I. (2022). Reducing age-related memory deficits: The roles of environmental support and self-initiated processing activities. *Experimental Aging Research*, 48(5), 401–427. <https://doi.org/10.1080/0361073X.2022.2084660>
- den Ouden, H. E. M., Kok, P., & de Lange, F. P. (2012). How prediction errors shape perception, attention, & motivation. *Frontiers in Psychology*, 3, 548. <https://doi.org/10.3389/fpsyg.2012.00548>
- Dreher, J. C., Meyer-Lindenberg, A., Kohn, P., & Berman, K. F. (2008). Age-related changes in midbrain dopaminergic regulation of the human reward system. *Proceedings of the National Academy of Sciences*, 105(39), 15106–15111. <https://doi.org/10.1073/pnas.0802127105>
- Dunlosky, J. (1998). Linking metacognitive theory to education. In D. J. Hacker, J. Dunlosky, & A. Grasser (Eds.), *Metacognition in educational theory and practice* (pp. 367–381). Lawrence Erlbaum and Associates.
- Elliott, B. L., Brewer, G. A., Zwaan, R., & Madan, C. (2019). Divided attention selectively impairs value-directed encoding. *Collabra: Psychology*, 5(1), 4. <https://doi.org/10.1525/collabra.156>
- Glimscher, P. W. (2011). Understanding dopamine and reinforcement learning: The dopamine reward prediction error hypothesis. *Proceedings of the National Academy of Science*, 108(supplement_3), 15647–15654. <https://doi.org/10.1073/pnas.1014269108>
- Greene, N. R., & Naveh-Benjamin, M. (2022). Online experimentation and sampling in cognitive aging research. *Psychology and Aging*, 37(1), 72–83. <https://doi.org/10.1037/pag0000655>
- Gruber, M. J., Ritchey, M., Wang, S. F., Doss, M. K., & Ranganath, C. R. (2016). Post-learning hippocampal dynamics promote preferential retention of rewarding events. *Neuron*, 89(5), 1110–1120. <https://doi.org/10.1016/j.neuron.2016.01.017>
- Hämmerer, D., & Eppinger, B. (2012). Dopaminergic and prefrontal contributions to reward-based learning and outcome monitoring during child development and aging. *Developmental Psychology*, 48(3), 862–874. <https://doi.org/10.1037/a0027342>
- Hargis, M. B., & Castel, A. D. (2018). Younger and older adults' associative memory for medication interactions of varying severity. *Memory*, 26(8), 1151–1158. <https://doi.org/10.1080/09658211.2018.1441423>
- Hargis, M. B., Siegel, A. L. M., & Castel, A. D. (2019). Motivated memory, learning, and decision making in older age: Shifts in priorities and goals. In G. Samanez-Larkin (Ed.), *The aging brain* (pp. 135–164). American Psychological Association.
- Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of Learning and Motivation*, 22, 193–225. [https://doi.org/10.1016/S0079-7421\(08\)60041-9](https://doi.org/10.1016/S0079-7421(08)60041-9)
- Hayes, M. G., Kelly, A. J., & Smith, A. D. (2013). Working memory and the strategic control of attention in older and younger adults. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 68(2), 176–183. <https://doi.org/10.1093/geronb/gbs057>
- Hennessee, J. P. (2018). *Value-directed remembering and aging: Examination of supporting mechanisms and effects on memory quality*. UCLA Dissertation.
- Hennessee, J. P., Patterson, T. K., Castel, A. D., & Knowlton, B. J. (2019). Forget me not: Encoding processes in value-directed remembering. *Journal of Memory and Language*, 106, 29–39. <https://doi.org/10.1016/j.jml.2019.02.001>
- Hennessee, J. P., Schorn, J. M., Walsh, C., Castel, A. D., & Knowlton, B. K. (2024). Goal-directed remembering in older adults. *Aging, Neuropsychology & Cognition*, 1–23. <https://doi.org/10.1080/13825585.2023.2282223>

- Hertzog, C., & Dunlosky, J. (1996). The aging of practical memory: An overview. *Basic and Applied Memory Research: Theory in Context*, 1, 337–358.
- Hertzog, C., Price, J., & Dunlosky, J. (2008). How is knowledge generated about memory encoding strategy effectiveness? *Learning and Individual Differences*, 18(4), 430–445. <https://doi.org/10.1016/j.lindif.2007.12.002>
- Hess, T. M. (2005). Memory and aging in context. *Psychological Bulletin*, 131(3), 383–406. <https://doi.org/10.1037/0033-2909.131.3.383>
- Jennings, J. M., & Jacoby, L. L. (1993). Automatic versus intentional uses of memory: Aging, attention, and control. *Psychology and Aging*, 8(2), 283–293. <https://doi.org/10.1037/0882-7974.8.2.283>
- Knowlton, B. J., & Castel, A. D. (2022). Memory and reward-based learning: A value-directed remembering perspective. *Annual Review of Psychology*, 73(1), 25–52. <https://doi.org/10.1146/annurev-psych-032921-050951>
- Luna, K., Nogueira, M., & Albuquerque, P. B. (2019). Words in larger font are perceived as more important: Explaining the belief that font size affects memory. *Memory*, 27(4), 555–560. <https://doi.org/10.1080/09658211.2018.1529797>
- Lustig, C., & Flegal, K. (2008). Age differences in memory: Demands on cognitive control and association processes. *Advances in Psychology*, 139, 137–149. [https://doi.org/10.1016/S0166-4115\(08\)10012-7](https://doi.org/10.1016/S0166-4115(08)10012-7)
- Mather, M., & Schoeke, A. (2011). Positive outcomes enhance incidental learning for both younger and older adults. *Frontiers in Neuroscience*, 5, 129. <https://doi.org/10.3389/fnins.2011.00129>
- McGillivray, S., & Castel, A. D. (2011). Betting on memory leads to metacognitive improvement by younger and older adults. *Psychology and Aging*, 26(1), 137–142. <https://doi.org/10.1037/a0022681>
- Middlebrooks, C. D., Kerr, T., & Castel, A. D. (2017). Selectively distracted: Divided attention and memory for important information. *Psychological Science*, 28(8), 1103–1115. <https://doi.org/10.1177/0956797617702502>
- Moors, A., & De Houwer, J. (2006). Automaticity: A theoretical and conceptual analysis. *Psychological Bulletin*, 132(2), 297–326. <https://doi.org/10.1037/0033-2909.132.2.297>
- Murphy, D. H. (2023a). Does point value structure influence measures of memory selectivity? *Memory*, 31(8), 1074–1088. <https://doi.org/10.1080/09658211.2023.2221006>
- Murphy, D. H. (2023b). Strategic offloading: How the value of to-be-remembered information influences offloading decision-making. *Applied Cognitive Psychology*, 37(4), 749–767. <https://doi.org/10.1002/acp.4051>
- Murphy, D. H., Agadzhanian, K., Whatley, M. C., & Castel, A. D. (2021). Metacognition and fluid intelligence in value-directed remembering. *Metacognition and Learning*, 16(3), 685–709. <https://doi.org/10.1007/s11409-021-09265-9>
- Murphy, D. H., & Castel, A. D. (2020). Responsible remembering: How metacognition impacts adaptive selective memory. *Zeitschrift für Psychologie*, 228(4), 301–303. <https://doi.org/10.1027/2151-2604/a000428>
- Murphy, D. H., & Castel, A. D. (2022a). Differential effects of proactive and retroactive interference in value-directed remembering for younger and older adults. *Psychology and Aging*, 37(7), 787–799. <https://doi.org/10.1037/pag0000707>
- Murphy, D. H., & Castel, A. D. (2022b). Responsible remembering and forgetting in younger and older adults. *Experimental Aging Research*, 48(5), 455–473. <https://doi.org/10.1080/0361073X.2022.2033592>
- Murphy, D. H., & Castel, A. D. (2022c). The role of attention and aging in the retrieval dynamics of value-directed remembering. *Quarterly Journal of Experimental Psychology*, 75(5), 954–968. <https://doi.org/10.1177/17470218211046612>
- Murphy, D. H., & Castel, A. D. (2023a). Age-related differences in memory when offloading important information. *Psychology and Aging*, 38(5), 415–427. <https://doi.org/10.1037/pag0000750>
- Murphy, D. H., & Castel, A. D. (2023b). Age-related differences in overcoming interference when selectively remembering important information. *Experimental Aging Research*, 50(2), 190–205. <https://doi.org/10.1080/0361073X.2023.2176629>

- Murphy, D. H., Hargis, M. B., & Castel, A. D. (2023). Younger and older adults' strategic use of associative memory and metacognitive control when learning foreign vocabulary words of varying importance. *Psychology and Aging, 38*(2), 103–116. <https://doi.org/10.1037/pag0000730>
- Murphy, D. H., & Knowlton, B. J. (2022). Framing effects in value-directed remembering. *Memory & Cognition, 50*(6), 1350–1361. <https://doi.org/10.3758/s13421-022-01317-y>
- Murphy, D. H., Rhodes, M. G., & Castel, A. D. (2024). *The perceived importance of words in large font guides learning and selective memory*. Memory & Cognition.
- Park, D. C., & Festini, S. B. (2017). Theories of memory and aging: A look at the past and a glimpse of the future. *Journals of Gerontology: Psychological Sciences, 72*(1), 82–90. <https://doi.org/10.1093/geronb/gbw066>
- Robison, M. K., & Unsworth, N. (2017). Working memory capacity, strategic allocation of study time, and value-directed remembering. *Journal of Memory and Language, 93*, 231–244. <https://doi.org/10.1016/j.jml.2016.10.007>
- Salthouse, T. A. (2010). Selective review of cognitive aging. *Journal of the International Neuropsychological Society, 16*(5), 754–760. <https://doi.org/10.1017/S1355617710000706>
- Salthouse, T. A. (2019). Trajectories of normal cognitive aging. *Psychology and Aging, 34*(1), 17–24. <https://doi.org/10.1037/pag0000288>
- Schultz, W. (2015). Neuronal reward and decision signals: From theories to data. *Physiological Review, 95*(3), 853–951. <https://doi.org/10.1152/physrev.00023.2014>
- Schwartz, S. T., Siegel, A. L. M., Eich, T. S., & Castel, A. D. (2023). Value-directed memory selectivity relies on goal-directed knowledge of value structure prior to encoding in young and older adults. *Psychology and Aging, 38*(1), 30–48. <https://doi.org/10.1037/pag0000720>
- Spaniol, J., Schain, C., & Bowen, H. J. (2014). Reward-enhanced memory in younger and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 69*(5), 730–740. <https://doi.org/10.1093/geronb/gbt044>
- Stefanidi, A., Ellis, D. M., & Brewer, G. A. (2018). Free recall dynamics in value-directed remembering. *Journal of Memory and Language, 100*, 18–31. <https://doi.org/10.1016/j.jml.2017.11.004>
- Storm, B. C., Hickman, M. L., & Bjork, E. L. (2016). Improving encoding strategies as a function of test knowledge and experience. *Memory & Cognition, 44*(4), 660–670. <https://doi.org/10.3758/s13421-016-0588-9>
- Swirsky, L. T., & Spaniol, J. (2019). Cognitive and motivational selectivity in healthy aging. *Wiley Interdisciplinary Reviews: Cognitive Science, 10*(6), e1512. <https://doi.org/10.1002/wcs.1512>
- Thomas, A. K., & Gutchess, A. (Eds.). (2020). *The Cambridge Handbook of cognitive aging: A life course perspective*. Cambridge University Press.
- Volkow, N. D., Ding, Y. S., Fowler, J. S., Wang, G. J., Logan, J., Gatley, S. J., Hitzemann, R., Smith, G., Fields, S. D., & Gur, R. (1996). Dopamine transporters decrease with age. *Journal of Nuclear Medicine, 37*(4), 554–559.
- Whatley, M. C., Murphy, D. H., Silaj, K. M., & Castel, A. D. (2021). Motivated memory for what matters most: How older adults (selectively) focus on important information and events using schematic support, metacognition, and meaningful goals. In G. Sedek, T. Hess, & D. Touron (Eds.), *Multiple pathways of cognitive aging: Motivational and contextual influences* (pp. 40–65). Oxford University Press.