AMERICAN PSYCHOLOGICAL ASSOCIATION

Psychology and Aging

ISSN: 0882-7974

2023, Vol. 38, No. 5, 415–427
https://doi.org/10.1037/pag0000750

Age-Related Differences in Memory When Offloading Important Information

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People can choose to use external memory aids and offload information to help them remember it, but it is unclear how objective and subjective value or importance influence offloading decisions in younger and older adults. We presented younger adults ($n = 99$; age range: 18–31) and older adults ($n = 93$; age range: 60–96) with items to remember for a later test and allowed them to offload a subset of the presented items. In Experiment 1, the to-be-remembered information was lists of associated words paired with point values counting toward participants' scores if recalled. In Experiment 2, the to-be-remembered information was lists of items along a theme, such as packing for vacation, which differed in subjective value. Results revealed that when words were paired with objective point values, younger adults were more selective in their offloading decisions and subsequent recall than older adults (i.e., younger adults were more likely to offload and recall high-value items than low-value items relative to older adults). When the to-be-remembered items instead differed in subjective value, older adults were more selective in their offloading decisions than younger adults. Specifically, older adults were more likely to offload words they rated as important relative to items they rated as less important while younger adults displayed the opposite pattern—younger adults were more likely to offload words they rated as less important compared with items they rated as more important. This difference in offloading tendencies when to-be-remembered information varies in subjective value may be indicative of older adults engaging in a form of metacognitive control that can help ensure the use of responsible remembering.

Public Significance Statement
People frequently use external memory aids and technology to offload information that is important to later remember. We found that when allowed to offload to-be-remembered information, younger adults are more likely to offload and subsequently remember objectively valuable information, while older adults are more likely to offload and subsequently remember intrinsically important information. These age-related differences in the use of memory aids to selectively remember important information may indicate that older adults are more responsible offloaders and rememberers.

Keywords: memory, aging, offloading, selectivity, responsible remembering

Offloading information can involve anything from writing something down on a sheet of paper to using your phone to help you remember something (see Dror & Harnad, 2008, for a discussion of how offloading impacts thinking). Cognitive offloading has many obvious benefits like being able to remember more information and reducing cognitive load (see Cherkaoui & Gilbert, 2017; Risko & Dunn, 2015; Risko & Gilbert, 2016; Sparrow et al., 2011; Storm & Stone, 2015; see Carter, 2018; Dawson, 2020, for educational implications), but there are also dangers to offloading. For example, offloaded information tends to be remembered more poorly than information that is not offloaded (e.g., Eskritt & Ma, 2014; Grinschgl, Papenmeier, et al., 2021; Kelly & Risko, 2019a, 2019b; Lu et al., 2020; Marsh & Rajaram, 2019) and if the external store is surprisingly unavailable (such as a dead phone battery or losing your notes), it may be difficult to recall offloaded information (see Kelly & Risko, 2021; Risko et al., 2019; see also Kelly & Risko, 2022).

Since offloading, assuming it is reliable (and people tend to rely more on an external store if it is perceived to be dependable, see Dupont et al., 2023; Schooler & Storm, 2021; Storm & Stone, 2015; see also Pereira et al., 2022), can increase the accessibility of information, it may be helpful to offload all information that needs to be remembered. However, this may not always be feasible and/or efficient; instead, people likely offload subsets of information. When deciding what information to offload, learners should engage in metacognitive monitoring (the evaluation of learning) and control

This article was published Online First May 11, 2023.
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This research was supported in part by the National Institutes of Health (National Institute on Aging; Award Number R01 AG044335 to Alan D. Castel). The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or nonfinancial interest in the subject matter or materials discussed in this article. The ideas and data appearing in the article have not been disseminated before. The experiments reported in this article were preregistered, and the stimuli and data have been made available on the Open Science Framework at https://osf.io/4hucn/?view_only=e8050e8be2464984ba6dbc3d8adaa301.
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(encoding decisions based on monitoring; see Rhodes, 2016, for a review). Specifically, learners should evaluate what information will be remembered or forgotten and use external stores to retain information that otherwise would have been forgotten. Thus, since metacognition can influence offloading decisions (Boldt & Gilbert, 2019; Dunn & Risko, 2016; Gilbert, 2015; Gilbert et al., 2020; Grinschgl, Meyerhoff, et al., 2021), learners need to use metacognitive control processes to decide when and what information to offload, and these processes may show age-related similarities and differences (see Castel et al., 2015; Hertzog, 2016), although metacognitive control processes have not been examined in an offloading context.

If a learner is only able to offload a subset of information (rather than all of it), it may be of the most benefit to offload the most valuable or important information as this could maximize the likelihood of retaining this information compared with the fallibility of memory (Castel & Rhodes, 2020; Schacter, 1999). When faced with too much information to remember, younger and older adults tend to prioritize the encoding and retrieval of high-value relative to low-value information. For example, Castel et al. (2002) presented younger and older adults with lists of words paired with point values counting toward participants' scores if recalled on later tests. In this value-directed remembering procedure, despite many cognitive deficits accompanying healthy aging (see D. C. Park & Festini, 2017; Hess, 2005; Salthouse, 2010, 2019; Thomas & Gutchess, 2020), older adults demonstrated a similar ability to recall the high-value words while recall for low-value words was reduced compared with younger adults (see also Murphy & Castel, 2022a, 2022b; see Knowlton & Castel, 2022; Madan, 2017, for a review). Thus, selective memory can be preserved or even enhanced in older age, and this may reflect a metacognitive awareness of the need to focus on important information in light of memory capacity limits (Castel, 2007).

In contrast to remembering lists of unassociated words differing in experimenter-designated, objective point values, younger and older adults can also prioritize the memory of information that is subjectively important. For example, Murphy and Castel (2022c) presented learners with a list of items to remember for a camping trip and demonstrated that both younger and older adults best remembered important information (e.g., "tent") compared with information of less importance (e.g., "shovel"; see also Murphy et al., 2023). This exemplifies the notion of *responsible remembering*, which involves enhanced memory for important information with consequences for forgetting as well as the metacognitive strategies and underlying mechanisms contributing to this form of selective memory (Murphy & Castel, 2020, 2021a, 2021b, 2022d; Murphy, Schwartz, et al., 2022; Murphy, Hoover, et al., 2022; Murphy & Knowlton, 2022).

In addition to remembering important information, responsible remembering involves strategic encoding operations that contribute to selective memory. For example, in prior work, we presented participants with pictures of children and their food preferences (foods they like, dislike, or are allergic to) to remember for a later test. When asked to consider the importance of each preference, learners prioritized the encoding and recall of the foods with the worst consequences for forgetting (the foods the child is allergic to) by spending the most time in studying those items (see Murphy & Castel, 2021b; Murphy, Hoover, et al., 2022). Thus, engaging in responsible remembering involves encoding operations employed by the learner to optimize memory utility and avoid negative outcomes for forgetting important information.

In the context of offloading, learners should use the external store to remember valuable information, but this may limit the availability of these items in memory. For example, J. S. Park et al. (2022) presented learners with low- and high-value information and told some participants that they could rely on an external store to help them remember the information. Results revealed that when participants were told that they could rely on the external store, the recall advantage for high-value relative to low-value information was reduced (i.e., selective memory decreased). Thus, learners were counting on the external store to remember high-value items rather than relying on memory, leading to the unexpected forgetting of valuable information when the external store was unavailable, a situation with potentially disastrous consequences in daily life (e.g., forgetting to pick up your kids from school if your alarm does not go off).

Again, the strategy of offloading valuable information incurs the potential risk of forgetting this information if the external store is not reliable. However, it is unclear how older adults utilize external stores to remember information and whether valuable information is encoded in memory even if older adults choose to offload it. Additionally, we were interested in how the objective and subjective value of information influences offloading decisions. Specifically, both younger and older adults may offload important information, but this may depend on a variety of factors, and the use of compensatory metacognitive control processes (cf. Castel et al., 2015; Hertzog & Dunlosky, 2011) may lead older adults to use offloading to ensure high-value information is retained.

The Present Study

Some prior work (primarily using self-report measures) indicates that people are more likely to use external stores to remember things when they are valuable (see Meacham & Singer, 1977; Murphy, 2023a; Penningroth & Scott, 2013). However, it remains unclear how older adults choose what information to offload and if offloaded information is quickly forgotten and not recallable, much like in a directed forgetting task (cf. Titz & Verhaeghen, 2010). In the present study, we presented younger and older adults with information to remember for a later test and allowed them to offload a subset of the presented items. In Experiment 1, the to-be-remembered information was lists of unassociated words paired with (objective) point values counting toward participants' scores if recalled. In Experiment 2, the to-be-remembered information was lists of items along a theme, such as items to pack for a vacation, which differed in subjective value.

Overall, since some evidence suggests that memory selectivity is preserved or even enhanced in older adults (e.g., Castel et al., 2002; Knowlton & Castel, 2022), we expected older adults to be more strategic in their offloading decisions (and subsequently more selective in their recall) as they may be more metacognitively aware of the need to be selective, especially on later lists after having some experience with the task (Whatley et al., 2021). Additionally, we expected older adults to be more selective when offloaded words were surprisingly unavailable. Specifically, while younger adults may be more accustomed to relying on external stores to remember information (perhaps via smartphones), older adults may have experienced more instances of forgetting important information when an external store was not reliable and/or no longer available. Thus, older adults may better encode offloaded, high-value items resulting in better memory for this information if the external store is surprisingly unavailable, though these possible effects may differ depending on whether item value is assigned objectively or subjectively (as it is likely that experimenter-designated point values make it easier to determine the hierarchy of importance of items within a list while subjective importance requires the learner to think more intrinsically about each item and the potential consequences of forgetting it which may consume more cognitive resources that could potentially be used to encode the item).

Experiment 1

In Experiment 1, we presented younger and older adults with lists of words to remember for a later test. Each list contained 15 words, and each word was paired with a point value counting toward participants' score if recalled on the test. During the encoding phase, we allowed participants to offload five words of their choosing and these offloaded words were available to them during the test (i.e., they did not need to be recalled from memory) on the first four lists. However, on the fifth list, the offloaded words were (surprisingly) unavailable to participants during the test. Last, participants completed a final free recall test for all studied words with no access to previously offloaded words as this may reveal how people remember (or fail to remember) important offloaded information when these items need to be accessed later. We were interested in whether there would be age-related differences in how younger and older adults choose to offload low-value and high-value information, if this would impact recall, and if younger and older adults would demonstrate forgetting of offloaded information.

Method

Transparency and Openness

We report an analysis of our sample size and describe all data exclusions, manipulations, and all measures in the study. All data and research materials are available on Open Science Framework (OSF). Data were analyzed using Jamovi (The jamovi project, 2022), and all information needed to reproduce the analyses is available. This study's design and its analysis were preregistered. Informed consent was acquired, and the study was completed in accordance with the University of California Los Angeles (UCLA) Institutional Review Board (Memory, Attention, Emotion and Aging: IRB No. 12-000617).

Participants

Data in each experiment were collected from September 2022 to October 2022. After exclusions, younger adults were 47 undergraduate students (age range: 18–22; M_{age} = 19.72, SD_{age} = 1.49; 41 female, 5 male, 1 other; 25 Asian/Pacific Islander, 1 Black, 2 Hispanic, 14 White, 5 other/unknown; in terms of the highest level of education achieved, 10 high school graduate, 28 some college but no degree, 8 associate's degree, 1 bachelor's degree) recruited from the UCLA Human Subjects Pool. Participants were tested online (but students were located in Los Angeles) and received course credit for their participation. Older adults (n = 35; age range: 65–83; M_{age} = 72.14, SD_{age} = 4.91; 21 female, 14 male; 2 Black, 33 White; 6 high school graduate, 5 some college but no degree, 6 associate's degree, 11 bachelor's degree; 7 graduate degree [master's, doctorate, etc.]) were recruited from Amazon's Cloud Research (Chandler et al., 2019), a website that allows users to complete small tasks for pay (which we have used in prior work, e.g., Murphy & Castel, 2022b; Murphy et al., 2023). Participants were all located in the United States. Participants were excluded from analysis if they admitted to cheating (e.g., writing down answers) in a posttask questionnaire (they were told they would still receive credit if they cheated). This exclusion process resulted in the exclusion of two younger adults and six older adults. We also excluded participants who did not offload at least 10 words throughout the task which resulted in the exclusion of 11 younger adults and 14 older adults.[1] We did not include any other validity checks. In each experiment, we aimed to collect around 50 participants per condition. The sample size was determined based on prior exploratory research and the expectation of detecting a medium effect size (consistent with some of our prior work using a similar design, e.g., Murphy & Castel, 2022b; Murphy & Knowlton, 2022). With the obtained sample, we had an 80% chance of detecting a *medium* effect (Cohen's d = .63) of age.

Materials

The to-be-remembered words (unrelated) were between four and seven letters (M = 5.04, SD = .98), and on the log-transformed Hyperspace Analogue to Language Frequency Scale (with lower values indicating lower frequency in the English language and higher values indicating higher frequency), ranged from 5.65 to 12.53 and averaged a score of 9.01 (SD = 1.44). In terms of concreteness (with lower values indicating lower concreteness and higher values indicating higher concreteness), words ranged from 3.10 to 4.97 and averaged a score of 4.55 (SD = .43). Words were classified according to the English Lexicon Project website (Balota et al., 2007).

Procedure

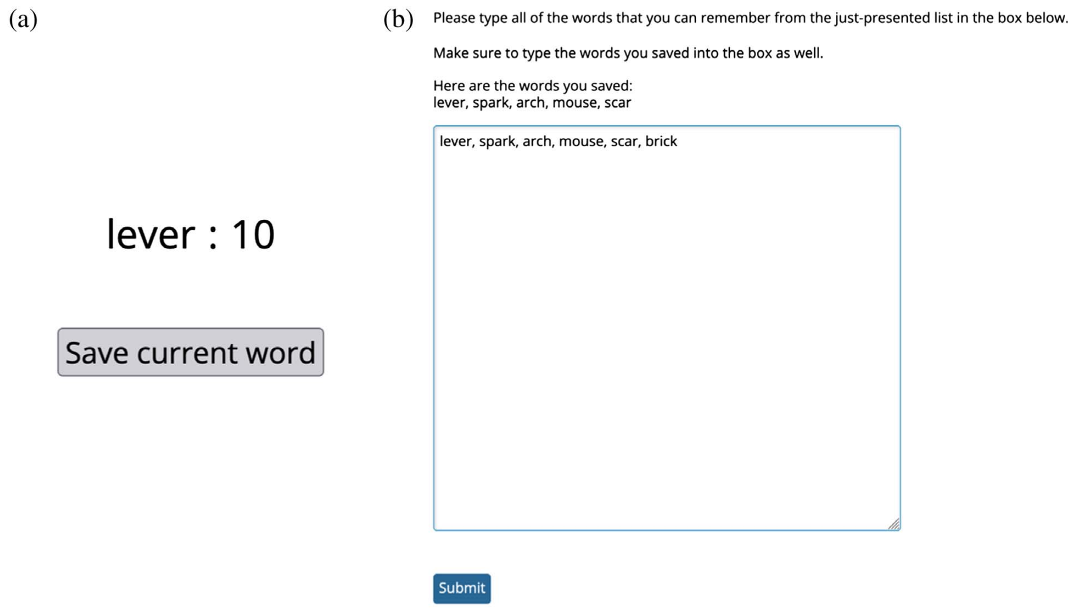
Participants were told that they would be presented with lists of unique, randomly selected to-be-remembered words with each word paired with a unique, randomly assigned value between 1 and 15 indicating how much the word was "worth." Each point value was used only once within each list and the order of the point values within lists was randomized. The stimulus words were presented for 3 s each with a 500 ms interstimulus interval between words (consistent with prior work, see Murphy & Castel, 2022b; Murphy et al., 2021; Murphy & Knowlton, 2022). After the presentation of all 15 word-number pairs in each list, participants were given a self-paced free recall test in which they had to recall as many words as they could from the list (they did not need to recall the point values). There were no practice trials.

On each list, participants were allowed to offload up to five words of their choice. To offload a word, participants clicked a button to add it to their external store (see Figure 1a); we do not have measures

[1] We did not preregister these exclusion criteria as we did not anticipate that some participants would not use most of the capacity of the external store. However, we think that it is important to only include participants who actually engaged in offloading as this was our primary research interest.

Figure 1

Example of the Study (a) and Test (b) Phase in Each Experiment



Note. Each word was presented in the middle of the screen and participants pressed the "Save current word" button to add the currently presented word to the external store. See the online article for the color version of this figure.

of response time for offloading decisions. During the test, offloaded words appeared at the top of participants' screens, and they were reminded to retype the offloaded words into the text box (see Figure 1b); we scored all offloaded words as correct even if participants did not type them into the box. Immediately following the recall period, participants were told their score (the sum of the values of the words they recalled) for that list but were not given feedback about specific items. On the first four lists, the offloaded words were available to participants on the test. However, on List 5, the offloaded words were surprisingly unavailable to participants (during the test, they were told "Sorry, you will not have access to the words you saved on this list"). Last, following the List 5 test, participants completed a final free recall test for all studied words without access to any offloaded words.

Analysis Plan

To examine differences in offloading behavior and recall, we computed multilevel models (MLMs) using Jamovi where we treated the data as hierarchical or clustered (i.e., multilevel) with items nested within individual participants (we also nested data for each word such that each participant and each word had their own intercept in the model); we did not treat the slope of value as a random effect. Since offloading and recall at the item level were binary (offloaded or not offloaded; correct or incorrect), we conducted logistic MLMs. In these analyses, the regression coefficients are given as logit units (i.e., the log odds of offloading/correct recall). We report exponential betas (e^B) and their 95% confidence intervals (95% CI), which give the coefficient as an odds ratio (i.e., the odds of offloading/correctly recalling a word divided by the odds of not offloading/recalling a word). Thus, e^B can be interpreted as the extent to which the odds of offloading/recalling a word changed. Specifically, values greater than 1 represent an increased likelihood of offloading/recall while values less than 1 represent a decreased likelihood of offloading/recall. In each analysis, we conducted logistic MLMs with item-level offloading/recall modeled as a function of value with age (young, old) as a between-subjects factor. In analyses involving recall, we included the number of words offloaded (participants were not required to offload five) as a predictor to control for differences in how many words participants offloaded (we do not report these effects but the data are available on OSF).

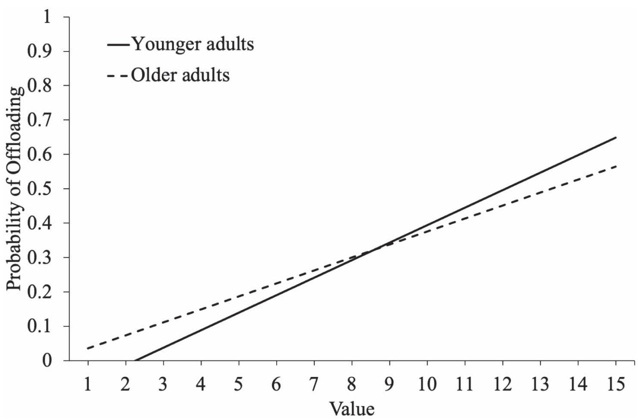
Results

We first examined how younger and older adults' offloading decisions were impacted by point values (see Figure 2). Results from our model (intraclass correlation [ICC] for participants <.01, $ICC_{words} < .01$[2]) revealed that value significantly predicted offloading ($e^B = 1.29$, 95% CI [1.27, 1.31], $z = 27.13$, $p < .001$) such that high-value words were offloaded more than low-value words. Additionally, age significantly predicted offloading ($e^B = .79$, 95% CI [.68, .92], $z = -3.05$, $p = .002$) such that older adults offloaded a greater proportion of words ($M = .30$, $SD = .05$, Min = .17, Max = .33) than younger adults ($M = .29$, $SD = .04$, Min = .20, Max = .33). Critically, value interacted with age ($e^B = 1.12$, 95% CI [1.08, 1.16],

[2] Low ICCs imply that there are minimal differences between participants or between words, though low ICCs occurred mostly for models of offloading (suggesting less variation in offloading behavior between participants). However, several of our models (primarily those involving recall) suggest differences between participants, indicating the need for multilevel models.

Figure 2

Linear Trend Lines for the Probability of Offloading as a Function of Point Value for Younger and Older Adults in Experiment 1



$z = 5.86$, $p < .001$) such that younger adults were more selective toward value when offloading relative to older adults. Specifically, an analysis of the simple effects revealed that value was a better predictor of offloading for younger adults ($e^B = 1.36$, 95% CI [1.33, 1.40], $z = 22.81$, $p < .001$) compared with older adults ($e^B = 1.22$, 95% CI [1.19, 1.25], $z = 15.42$, $p < .001$).

As an exploratory analysis suggested by reviewers, we also examined how younger and older adults' offloading decisions were impacted by factors known to impact memory like word length and frequency (e.g., Murphy & Castel, 2022e). Specifically, in a similar model as described above, we modeled offloading as a function of word length, frequency, and age group. Results from our model ($ICC_{participants} < .01$, $ICC_{words} < .01$) revealed that word length significantly predicted offloading ($e^B = 1.13$, 95% CI [1.05, 1.21], $z = 3.46$, $p < .001$) such that longer words were more likely to be offloaded than shorter words. However, word frequency did not predict offloading ($e^B = .98$, 95% CI [.94, 1.03], $z = -.74$, $p = .458$) but age interacted with frequency ($e^B = .84$, 95% CI [.76, .92], $z = -3.73$, $p < .001$) such that younger adults were more likely to offload low-frequency words ($e^B = .90$, 95% CI [.84, .96], $z = -3.35$, $p < .001$) while older adults are more likely to offload high-frequency words ($e^B = 1.07$, 95% CI [1.00, 1.15], $z = 2.00$, $p = .045$). Additionally, age interacted with word length ($e^B = .84$, 95% CI [.73, .96], $z = -2.53$, $p = .011$) such that older adults were more likely to offload longer words relative to shorter words ($e^B = 1.23$, 95% CI [1.11, 1.37], $z = 3.96$, $p < .001$) while younger adults did not incorporate word length into their offloading decisions ($e^B = 1.03$, 95% CI [.94, 1.13], $z = .71$, $p = .479$).

As a second exploratory analysis suggested by reviewers, we also examined how younger and older adults' offloading decisions were impacted by serial position (see Kausler, 1994; Murdock, 1962). Again, in a similar model as described above, we modeled offloading as a function of serial position and age group (see Figure 3). Results from our model ($ICC_{participants} < .01$, $ICC_{words} < .01$) revealed that serial position predicted offloading ($e^B = .92$, 95% CI [.91, .93], $z = -10.83$, $p < .001$) such that the earlier a word was presented, the more likely it was to be offloaded. Additionally, age interacted with serial position ($e^B = 1.13$, 95% CI [1.09, 1.16], $z = 7.70$, $p < .001$) such that serial position effects had a greater influence on older adults' offloading ($e^B = .87$, 95% CI [.85, .89], $z = -11.87$, $p < .001$) relative to younger adults ($e^B = .98$, 95% CI [.96, .99], $z = -2.50$, $p = .012$).

Next, we examined recall (which includes words that had been offloaded) on Lists 1–4 when younger and older adults were given access to the words that they offloaded on the recall test (see Figure 4). Results from our model ($ICC_{participants} = .09$, $ICC_{words} < .01$) revealed that value significantly predicted recall ($e^B = 1.18$, 95% CI [1.16, 1.19], $z = 20.64$, $p < .001$) such that high-value words were better recalled than low-value words. Additionally, age significantly predicted recall ($e^B = 1.91$, 95% CI [1.43, 2.54], $z = 4.41$, $p < .001$) such that younger adults recalled a greater proportion of words ($M = .63$, $SD = .13$, Min = .37, Max = .90) than older adults ($M = .51$, $SD = .13$, Min = .25, Max = .90). Critically, value interacted with age ($e^B = 1.11$, 95% CI [1.07, 1.14], $z = 6.53$, $p < .001$) such that younger adults more selectively recalled high-value words relative to older adults. Specifically, an analysis of the simple effects revealed that value was a better predictor of recall for younger adults ($e^B = 1.24$, 95% CI [1.21, 1.26], $z = 19.13$, $p < .001$) compared with older adults ($e^B = 1.12$, 95% CI [1.09, 1.14], $z = 10.09$, $p < .001$).

On List 5, participants were able to offload words but were not aware that they would not have access to these words on the recall test. Results from our model ($ICC_{participants} = .13$, $ICC_{words} = .02$) of recall on List 5[3] (see Figure 5) revealed that value significantly (but negatively) predicted recall ($e^B = .95$, 95% CI [.92, .98], $z = -3.51$, $p < .001$) such that low-value words were better recalled than high-value words. Additionally, age significantly predicted recall ($e^B = 1.53$, 95% CI [1.02, 2.28], $z = 2.06$, $p = .039$) such that younger adults recalled a greater proportion of words ($M = .38$, $SD = .17$, Min = .07, Max = .87) than older adults ($M = .30$, $SD = .20$, Min = 0, Max = .87). However, value did not interact with age ($e^B = 1.00$, 95% CI [.94, 1.06], $z = .07$, $p = .946$) such that younger and older adults demonstrated a similar tendency to recall low-value items while forgetting high-value items.

Last, we examined performance on the surprise final free recall test for all the studied words (no offloaded words were available to participants on this test) as a function of value and age group (see Figure 6). Results from our model ($ICC_{participants} = .18$, $ICC_{words} = .02$) revealed that value significantly and negatively predicted recall ($e^B = .96$, 95% CI [.95, .98], $z = -3.82$, $p < .001$) such that low-value words were better recalled than high-value words. Additionally, age significantly predicted recall ($e^B = 2.02$, 95% CI [1.33, 3.83], $z = 3.27$, $p = .001$) such that younger adults recalled a greater proportion of words ($M = .15$, $SD = .10$, Min = 0, Max = .59) than older adults ($M = .10$, $SD = .10$, Min = 0, Max = .35). However, value did not interact with age ($e^B = 1.02$, 95% CI [.99, 1.06], $z = 1.22$, $p = .222$) such that both younger and older adults were more likely to recall low-value relative to high-value items.

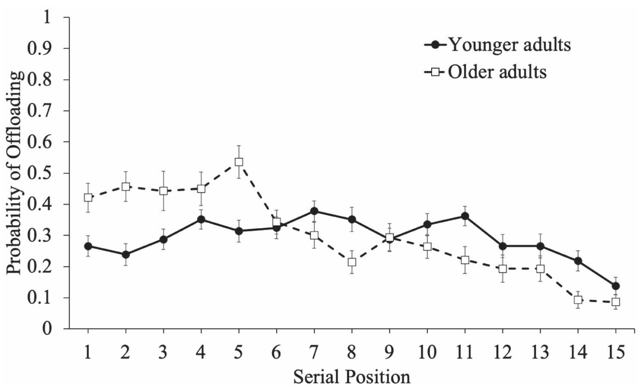
Discussion

In Experiment 1, younger adults were more selective in their offloading decisions than older adults. Specifically, younger adults were more likely to offload high-value words and less likely to offload low-value words relative to older adults. This trend was

[3] We note that analyses of List 5 contain fewer observations (15) than the analyses of Lists 1–4 (60) or the final free recall test (75).

Figure 3

The Probability of Offloading as a Function of Serial Position in Experiment 1

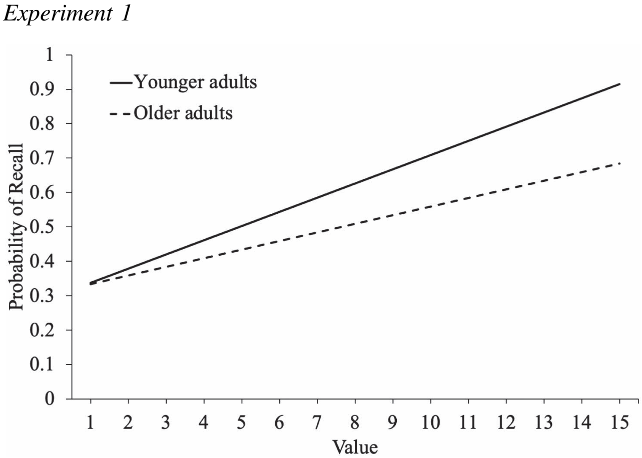


Note. Error bars reflect the standard error of the mean.

borne out in their recall such that, on Lists 1–4, younger adults better recalled valuable information relative to low-value information compared with older adults. However, on List 5 when offloaded words were surprisingly unavailable, both younger and older adults frequently forgot high-value words (the words they tended to offload), resulting in negative selectivity (better memory for low- relative to high-value words). Similarly, on a final free recall test for all studied words (without access to any offloaded words), younger and older adults again demonstrated negative selectivity such that low-value words were recalled better than high-value words. Together, Experiment 1 demonstrates that younger adults are more sensitive to the objective value of information when making offloading decisions compared with older adults but offloading valuable information can be risky as if the external store is unreliable, both younger and older adults demonstrated frequent forgetting of valuable information.

Figure 4

Linear Trend Lines for the Probability of Recall as a Function of Point Value for Younger and Older Adults on Lists 1–4 in Experiment 1



Experiment 2

In Experiment 2, we were interested in how younger and older adults engage in offloading when information differs in subjective value rather than objective value. To examine how subjective importance can influence memory, we used a procedure where participants studied lists of words that were semantically related (e.g., items to bring on a camping trip) as prior work using this type of to-be-remembered list has demonstrated the strategic remembering of important items ("water") as well as forgetting of items that are less relevant ("axe") or that one is not required to remember (McGillivray & Castel, 2017; Murphy & Castel, 2022c). After studying, offloading, and being tested on these items, participants were shown the list of words again and asked to rate the importance of each item in the list in terms of remembering them for that situation (e.g., when going camping). We then used these importance ratings to evaluate how subjective value influenced offloading and memory. We expected both younger and older adults to offload items that they considered important. Alternatively, learners may prioritize these important items in memory and utilize the external store for less important items to maximize total output.

Method

Participants

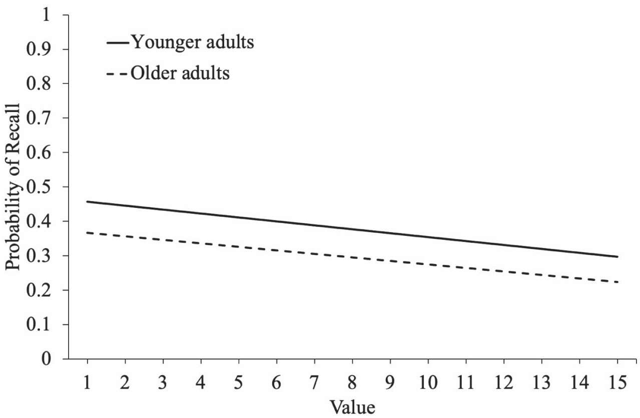
After exclusions, younger adults were 52 undergraduate students (age range: 18–31; $M_{age} = 20.06$, $SD_{age} = 1.96$; 43 female, 7 male, 2 other; 29 Asian/Pacific Islander, 1 Black, 4 Hispanic, 11 White, 7 other/unknown; 10 high school graduate, 30 some college but no degree, 9 associate's degree, 2 bachelor's degree) recruited from the UCLA Human Subjects Pool. Participants were tested online and received course credit for their participation. Older adults ($n = 58$; age range: 60–96; $M_{age} = 72.21$, $SD_{age} = 6.39$; 33 female, 25 male; 3 Black, 1 Hispanic, 53 White, 1 other/unknown; 1 some high school, 12 high school graduate, 11 some college but no degree, 7 associate's degree, 16 bachelor's degree, 11 graduate degree) were recruited from Amazon's Cloud Research. This exclusion process resulted in the exclusion of no younger adults and four older adults. Again, we also excluded participants who did not offload at least 10 words throughout the task which resulted in the exclusion of 11 younger adults and nine older adults. With the obtained sample, we had an 80% chance of detecting a *medium* effect (Cohen's $d = .54$) of age.

Materials and Procedure

The procedure in Experiment 2 was similar to Experiment 1. Participants were told that they would be presented with lists of words to remember for a later test with each list being along a theme and that they should try to imagine themselves in that situation. Participants were then presented with five lists of 15 words, with each list containing items along a theme (going camping, going on vacation, throwing a child's party, going to class, and going on a picnic; stimuli were adapted from McGillivray & Castel, 2017, are available on OSF). Each word was presented one at a time, for 3 s each, and in random order; list themes occurred in a fixed order. During the study phase, participants were allowed to offload up to five words of their choosing (using the same procedure as Experiment 1). After the presentation of all 15 words, participants were

Figure 5

Linear Trend Lines for the Probability of Recall as a Function of Point Value for Younger and Older Adults on List 5 in Experiment 1



given a self-paced free recall test in which they were asked to recall all the words from the just-presented list. Following each study–test cycle, participants were shown the words from that list, one at a time (in alphabetical order), and asked to rate the words from that list on a scale of how important it would be to remember them from 1 (*not at all important to remember*) to 7 (*very important to remember*). Again, as in Experiment 1, on List 5 offloaded words were (surprisingly) unavailable to participants and after List 5, participants completed a final free recall test (self-paced) for all studied words without access to any offloaded words.

Results

Rather than using the point value paired with each word (as in Experiment 1), for each analysis in Experiment 2, we conducted a logistic MLM with item-level offloading/recall modeled as a function of each participant's own importance ratings with age (young, old) as a between-subjects factor. We first examined how younger and older adults' offloading decisions were impacted by importance ratings (see Figure 7). Results from our model ($ICC_{participants}$ < .01, ICC_{words} = .02) revealed that importance ratings significantly predicted offloading (e^B = 1.09, 95% CI [1.05, 1.13], z = 4.67, p < .001) such that items rated as important to remember were offloaded more than items rated as less important. However, age did not significantly predict offloading (e^B = .96, 95% CI [.86, 1.07], z = −.74, p = .462) such that older adults offloaded a similar proportion of items (M = .31, SD = .04, Min = .18, Max = .33) as younger adults (M = .29, SD = .05, Min = .17, Max = .33). Critically, value interacted with age (e^B = .69, 95% CI [.65, .74], z = −11.22, p < .001) such that older adults were more selective toward item importance when offloading relative to younger adults. Specifically, an analysis of the simple effects revealed that importance ratings were a positive predictor of offloading for older adults (e^B = 1.30, 95% CI [1.25, 1.36], z = 11.46, p < .001) but a negative predictor for younger adults (e^B = .91, 95% CI [.86, .95], z = −3.95, p < .001).

As in Experiment 1, we also examined how younger and older adults' offloading decisions were impacted by word length and frequency. Specifically, in a similar model as described above, we modeled offloading as a function of word length, frequency, and age group. Results from our model ($ICC_{participants}$ < .01, ICC_{words} = .01) revealed that word length significantly predicted offloading (e^B = 1.07, 95% CI [1.02, 1.14], z = 2.57, p = .010) such that longer words were more likely to be offloaded than shorter words. However, word frequency did not predict offloading (e^B = .98, 95% CI [.92, 1.04], z = −.64, p = .524) but age interacted with frequency (e^B = .82, 95% CI [.76, .90], z = −4.61, p < .001) such that younger adults were more likely to offload low-frequency words (e^B = .89, 95% CI [.83, .96], z = −3.07, p = .002) while older adults are more likely to offload high-frequency words (e^B = 1.08, 95% CI [1.01, 1.16], z = 2.18, p = .030). Additionally, age interacted with word length (e^B = .91, 95% CI [.84, .98], z = −2.47, p = .013) such that older adults were more likely to offload longer words relative to shorter words (e^B = 1.13, 95% CI [1.06, 1.20], z = 3.58, p < .001) while younger adults did not incorporate word length into their offloading decisions (e^B = 1.02, 95% CI [.96, 1.10], z = .71, p = .476).

We also examined how younger and older adults' offloading decisions were impacted by serial position. Again, in a similar model as described above, we modeled offloading as a function of serial position and age group (see Figure 8). Results from our model ($ICC_{participants}$ < .01, ICC_{words} = .02) revealed that serial position predicted offloading (e^B = .90, 95% CI [.88, .91], z = −16.21, p < .001) such that the earlier a word was presented, the more likely it was to be offloaded. Additionally, age interacted with serial position (e^B = 1.13, 95% CI [1.11, 1.17], z = 9.41, p < .001) such that serial position effects had a greater influence on older adults' offloading (e^B = .84, 95% CI [.83, .86], z = −17.78, p < .001) relative to younger adults (e^B = .96, 95% CI [.94, .97], z = −4.91, p < .001).

Next, we examined recall on Lists 1–4 when younger and older adults were given access to the items that they offloaded on the recall test (see Figure 9). Results from our model ($ICC_{participants}$ = .12, ICC_{words} = .02) revealed that importance ratings significantly predicted recall (e^B = 1.21, 95% CI [1.17, 1.26], z = 10.14, p < .001) such that items rated as important were better recalled than items rated as less important. Additionally, age significantly predicted recall (e^B = 2.28, 95% CI [1.73, 3.01], z = 5.80, p < .001) such that younger adults recalled a greater proportion of items (M = .70, SD = .14, Min = .23, Max = .92) than older adults (M = .54,

Figure 6

Linear Trend Lines for the Probability of Recall as a Function of Point Value for Younger and Older Adults on the Final Recall Test for all Words in Experiment 1

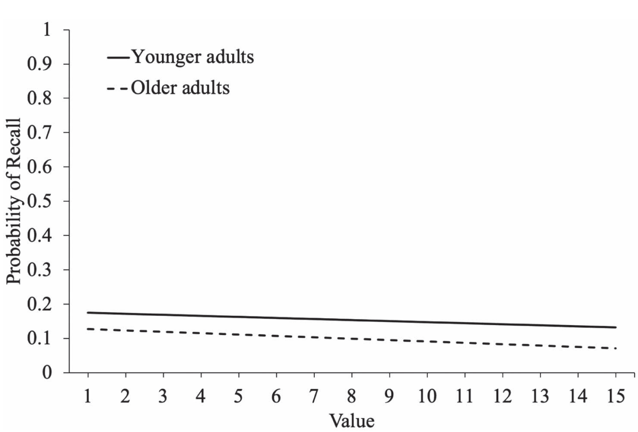
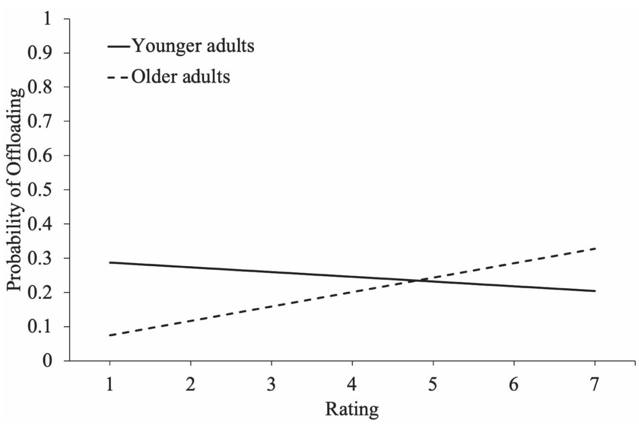


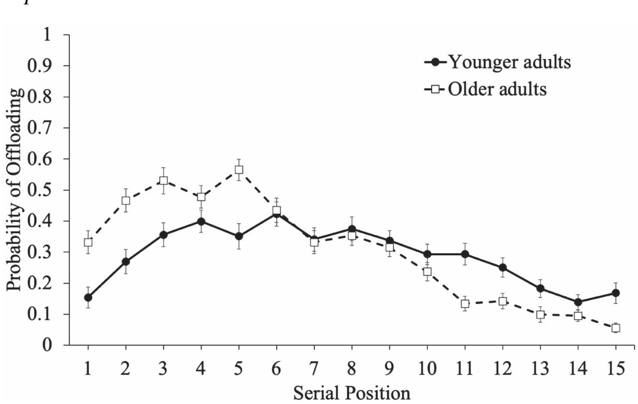
Figure 7
Linear Trend Lines for the Probability of Offloading as a Function of Importance Ratings for Younger and Older Adults in Experiment 2



SD = .17, Min = .28, Max = .85). Critically, value interacted with age (e^B = .78, 95% CI [.73, .84], $z = -7.22$, $p < .001$) such that older adults more selectively recalled items they considered important relative to younger adults. Specifically, an analysis of the simple effects revealed that importance ratings were a better predictor of recall for older adults (e^B = 1.37, 95% CI [1.31, 1.44], $z = 13.22$, $p < .001$) compared with younger adults (e^B = 1.07, 95% CI [1.02, 1.13], $z = 2.55$, $p = .011$).

On List 5, participants were able to offload items but were not aware that they would not have access to these items on the recall test. Results from our model ($ICC_{participants} = .20$, $ICC_{words} = .05$) of recall on List 5 (see Figure 10) revealed that importance ratings significantly predicted recall (e^B = 1.39, 95% CI [1.27, 1.51], $z = 7.48$, $p < .001$) such that important items were better recalled than items judged as less important. Additionally, age significantly predicted recall (e^B = 2.04, 95% CI [1.35, 3.09], $z = 3.36$, $p < .001$) such that younger adults recalled a greater proportion of items (*M* = .52, *SD* = .18, Min = .07, Max = .80) than older adults (*M* = .40, *SD* = .23, Min = 0, Max = .80). However, value did not interact with age (e^B = .94, 95% CI [.81, 1.09], $z = -.85$, $p = .397$) such that younger and older adults demonstrated a similar tendency to recall items they rated as important better than items they judged as less important.

Figure 8
The Probability of Offloading as a Function of Serial Position in Experiment 2



Note. Error bars reflect the standard error of the mean.

Last, we examined performance on the surprise final free recall test for all the studied items as a function of participants' own importance ratings and age (see Figure 11). Results from our model ($ICC_{participants} = .26$, $ICC_{words} = .15$) revealed that importance ratings significantly predicted recall (e^B = 1.17, 95% CI [1.12, 1.21], $z = 7.47$, $p < .001$) such that items that were rated as important to remember were remembered better than items rated as less important. Additionally, age significantly predicted recall (e^B = 3.11, 95% CI [2.03, 4.77], $z = 5.19$, $p < .001$) such that younger adults recalled a greater proportion of items (*M* = .55, *SD* = .16, Min = .03, Max = .84) than older adults (*M* = .38, *SD* = .17, Min = 0, Max = .77). However, value did not interact with age (e^B = 1.01, 95% CI [.94, 1.08], $z = .19$, $p = .850$) such that both younger and older adults recalled items they rated as important better than items they judged as less important.

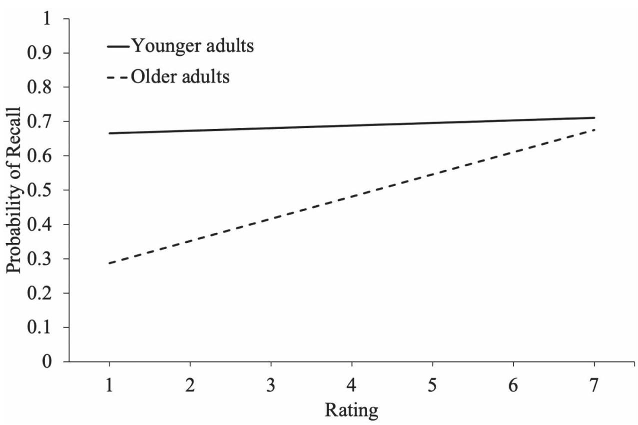
Discussion

In Experiment 2, older adults offloaded more items that they considered important to remember relative to items they judged as less important. In contrast, younger adults offloaded more items they rated as less important compared to items they judged as more important. As a result, older adults better recalled items they rated as important relative to younger adults. However, when the external store was surprisingly unavailable on List 5, both younger and older adults similarly better recalled items they rated as important to remember relative to items they considered less important. Similarly, on the final free recall test when the external store was also not available, younger and older adults again demonstrated a similar ability to better recall items they considered important compared with items they judged as less important to remember. Collectively, Experiment 2 illustrates that when information differs in subjective importance, older adults prioritize this information more so than younger adults in terms of their offloading decisions and subsequent recall. However, in the absence of the external store, important information is still remembered better than less important information such that under these conditions (goal-based memory of semantically related items), both younger and older adults can use memory efficiently.

General Discussion

In the present study, we presented younger and older adults with words to remember for a later test but allowed them to offload a subset of these words. On most of the recall tests, participants were given access to the words they offloaded. However, on the last list that participants studied, they were not given access to the words they offloaded. Additionally, we included a final free recall test for all studied words where participants did not have access to any offloaded words. In Experiment 1, the to-be-remembered words were unassociated and were paired with objective point values counting toward participants' scores if recalled. In Experiment 2, the to-be-remembered words were along a theme, such as items to pack for a vacation, and as such, varied in subjective value (to gauge

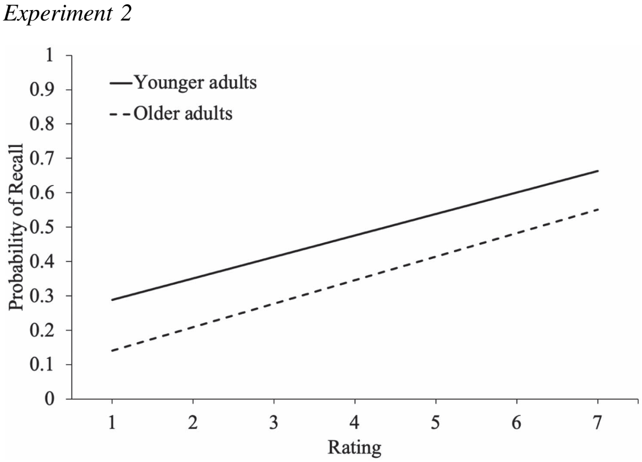
Figure 9
Linear Trend Lines for the Probability of Recall as a Function of Importance Ratings for Younger and Older Adults on Lists 1–4 in Experiment 2



the relative importance of each item for each participant, we had participants rate the importance of each item following each recall test).

Results revealed that when words were paired with objective point values counting toward their scores if recalled, younger adults were more selective in their offloading decisions than older adults (i.e., younger adults were more likely to offload high-value items than low-value items relative to older adults). This indicates that younger adults were more strategic in terms of offloading high-value items to enhance their score, and this strategy benefited their recall performance. The enhanced selectivity in younger adults' recall contrasts prior work suggesting that, in the absence of memory aids, older adults are similarly selective or even more selective than younger adults by recalling high-value items at a similar rate as younger adults and forgetting low-value items (see Knowlton & Castel, 2022, for a review). However, since younger adults in the present study were more likely to offload high-value items, thus guaranteeing the recall of these items on the test, older adults' selectivity suffered as a result of not using this strategy to the same extent.

Figure 10
Linear Trend Lines for the Probability of Recall as a Function of Importance Ratings for Younger and Older Adults on List 5 in Experiment 2

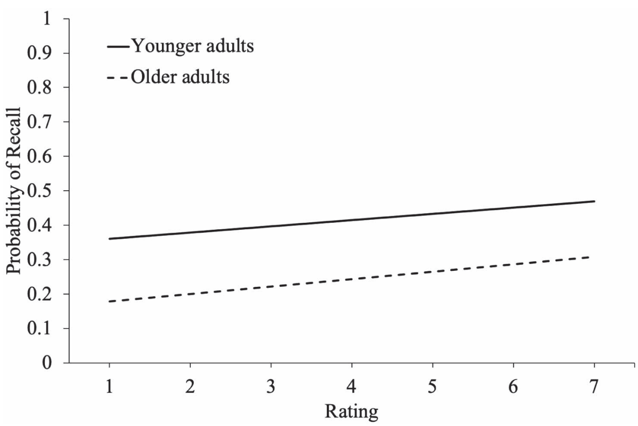


In Experiment 2, when the to-be-remembered items were not paired with objective point values but instead differed in subjective value, older adults were more selective in their offloading decisions than younger adults. Specifically, older adults were more likely to offload words they rated as important relative to items they rated as less important while younger adults displayed the opposite pattern—younger adults were more likely to offload words they rated as less important compared with items they rated as more important. This difference in offloading tendencies when to-be-remembered information differs in subjective value may be indicative of older adults as responsible remembers (Murphy & Castel, 2020). For example, having experienced more instances of forgetting, older adults may have become more tuned to using technology (i.e., a phone or notepad) to assist them in remembering important information with consequences if forgotten (i.e., forgetting your passport when packing for a vacation could have severe consequences). In contrast, younger adults may have been more confident in their memory performance for important items and also their ability to harness the schematic support of the list structure (e.g., if the theme of a list is items for a birthday party, "cake" is a high probability item and could potentially be recalled even if not encoded; these items that are more schematically consistent with the theme may also be considered important). As a result, younger adults may have strategically prioritized the offloading of items they considered harder to remember or less important as they were able to remember the important items even without the memory aid (as seen on List 5 when offloaded words were not accessible on the test).

While offloading information can increase the total amount of information accessible during recall, there are drawbacks to offloading. For example, if the external store is surprisingly unavailable, information that has been offloaded may be forgotten if it was not sufficiently encoded (see Murphy, 2023a). In Experiment 1, when the external store was surprisingly taken away, both younger and older adults frequently forgot high-value words indicating that these items received less encoding than low-value words which were better recalled. This finding again illustrates the potential dangers of offloading, although both younger and older adults were similarly afflicted by the surprising unavailability of the valuable items that they had offloaded. This form of selective forgetting may be similar to mechanisms involved in the directed forgetting of no longer relevant information (Titz & Verhaeghen, 2010; Zacks et al., 1996) as both younger and older adults may not recall items that were initially marked as not being necessary to later remember.

Despite the negative selectivity (i.e., recalling low-value items better than high-value items) we observed when unassociated words were paired with objective point values and the external store was surprisingly taken away, when to-be-remembered information differed in subjective value, both younger and older adults retained the ability to recall items they considered important to remember better than items they considered less important to remember. Specifically, even in the absence of the external store (which older adults had used to remember important items), younger and older adults demonstrated similar selective memory for items they rated

Figure 11
Linear Trend Lines for the Probability of Recall as a Function of Importance Ratings for Younger and Older Adults on the Final Recall Test for All Words in Experiment 2



as important to remember. This suggests that both younger and older adults may have been able to harness their semantic knowledge (e.g., F. I. M. Craik, 2022; Lalla et al., 2022; Mohanty et al., 2016) when encoding and making offloading decisions and apply this knowledge to the schematic structure of the list to assist in the recall of important items that may also be highly consistent with the theme of the list. Thus, when one can use goal-based memory when studying and recalling semantically related items, both younger and older adults can use memory efficiently to remember subjectively important information. This ability exemplifies responsible remembering (Murphy & Castel, 2020) in both younger and older adults such that recalling these items may help prevent the negative consequences of forgetting (i.e., forgetting water on a long camping trip could be deadly) and provides insight regarding the adaptive use of "personal" memory when external memory devices are unreliable. Additionally, older adults may benefit from the context of the memory task (e.g., Hess, 2005), which may be more similar to naturalistic memory challenges that are involved in remembering important information.

Again, in Experiment 1, younger adults were more sensitive to objective value in their offloading decisions compared with older adults but we observed the inverse in Experiment 2: Older adults were more sensitive to subjective value than younger adults. As such, when information varies in subjective importance, younger adults may be aiming to maximize the total amount of information accessible at the expense of prioritizing certain items while older adults focus on avoiding forgetting important information. Thus, consistent with life span theories of motivation (e.g., Freund et al., 2012), older adults' motivation may shift from seeking gains to avoiding losses (in this case, forgetting one's passport for a vacation or forgetting the tent on a camping trip).

Younger adults' offloading (and thus subsequent recall) of the items they rated as less important plus their potentially enhanced ability to use the schematic structure of the list to recall schema-consistent, important items led to the minimal selective recall of important items (importance ratings only weakly predicted recall). In contrast, older adults offloaded the items they considered important to remember, making these items easy to recall on the test (they have access to these words) but perhaps making it more difficult to retrieve the less schema-consistent, unimportant items. Thus, the differences in memory selectivity observed in Experiments 1 and 2 are likely attributable to younger adults' different strategies depending on the nature of the to-be-remembered information. Specifically, older adults may be more inclined to use value-based offloading strategies in situations that are more akin to remembering goal-relevant information that has consequences if forgotten in a more contextualized naturalistic setting (e.g., Hess, 2005) and when there is sufficient schematic support (e.g., Castel, 2005; F. I. Craik & Bosman, 1992) to guide value-directed remembering.

As a result of these potential strategic differences, there may be age-related differences in metacognitive control decisions that led younger adults to engage in offloading differently than older adults (to optimize value-based goals). In the present paradigm, the decision to offload a given item is a metacognitive control process that is the result of some metacognitive monitoring. Since younger adults are generally metacognitively aware of the need to be selective (Murphy et al., 2021), this may have contributed to their more strategic offloading of high-value words. However, offloading decisions may depend on both the objective and subjective value that is paired with the to-be-remembered information, and future research could examine how the level of confidence and/or interest one has in "personally" remembering information versus the reliance on external memory devices influences age-related differences offloading behavior. Additionally, in the present study, participants assessed the importance of remembering each item after the recall test which may be contaminated by recall success/failure. Future work could ask participants to assess item importance before recall or have a panel of independent raters evaluate the importance of each item rather than the participants (see McGillivray & Castel, 2017).

In exploratory analyses, the present study demonstrated age-related differences in how participants incorporate word characteristics like length and frequency (which typically affect memorability, e.g., Murphy & Castel, 2022e) into their offloading decisions. Specifically, across experiments, results revealed that younger adults were more likely to offload low-frequency words while older adults are more likely to offload high-frequency words. Prior work indicates that frequent words (words with a higher incidence rate) are better recalled than less frequent words (Hall, 1954; McDaniel & Bugg, 2008). Thus, in terms of word frequency, younger adults made better offloading decisions (i.e., if low-frequency words are harder to remember, these words should be offloaded). In terms of word length, short words (number of letters) are generally better remembered than long words (Baddeley et al., 1975). Here, older adults were more likely to offload longer words relative to shorter words while younger adults did not incorporate word length into their offloading decisions. This indicates that, in contrast to word frequency, older adults were better than younger adults at incorporating word length into their offloading decisions. Together, this indicates that learners likely incorporate intrinsic qualities of information when making offloading decisions, but future work is needed to better understand how younger and older adults differentially use this information to guide their offloading as well as whether self-paced study time during encoding could influence how effectively people make these decisions.

In addition to the intrinsic qualities of the items like frequency and length, as an exploratory analysis, we also investigated how serial position effects (see Kausler, 1994; Murdock, 1962) influenced offloading decisions as people may or may not use serial position information to guide metacognition (Castel, 2008). Prior work has demonstrated that offloading reduces the primacy effect in recall but not the recency effect (Kelly & Risko, 2019b), but serial position effects have not been examined in terms of offloading decisions. In the present experiments, results revealed that the earlier an item was presented, the more likely it was to be offloaded, and this trend was more pronounced in older adults. This is consistent with some prior work suggesting that learners recruit metacognitive insights regarding serial position effects to flatten the serial position curve (see Murphy, Friedman, et al., 2022). Here, the greater tendency to offload early list items in older adults potentially suggests that older adults feel that they may rapidly forget items from earlier in the list (i.e., show a reduced primacy effect due to interference and forgetting, see Castel et al., 2009) and thus offload these earlier items, although future research is needed to determine if this is a strategic effect that benefits older adults. Moreover, future work could examine whether additional practice trials or task experience influence age-related differences in how people approach the offloading/memory tasks as additional practice and task experience may allow older adults to use more efficient strategies to combat age-related differences in memory and to learn to offload items that are objectively important and/or difficult to remember.

In the present study, we used offloading decisions as a measure of metacognition as the optimal learner should predict which items will be remembered and offload the highest-valued items that will not be remembered. However, future work may benefit from examining other forms of metacognition such as judgments of learning (metacognitive monitoring) and/or allowing learners to self-pace their study time (metacognitive control). Additionally, participants that did not offload five words on each list may have had to divide their cognitive resources among a larger pool of words (i.e., rather than 10 words to remember if five are offloaded, participants would need to remember 12 words if they only offloaded three), and future work could use a procedure that requires all participants to offload the same number of words. Moreover, future work could examine how stereotype threat (see Barber & Mather, 2014; Fourquet et al., 2020) impacts offloading decisions as older adults may lack confidence in their memory abilities leading to a greater reliance on external stores in some circumstances. Finally, we did not include measures of cognitive functioning, mood, or vocabulary which may be important measures and/or exclusion criteria in future work.

In sum, the present study demonstrates that younger adults are often strategic in their offloading of information that differs in objective value while older adults are more likely to offload information that they consider important to remember. As a result of these offloading decisions, younger adults can better recall high-value information relative to older adults, but older adults may be more responsible remembers such that when information differs in subjective value, their use of the external store led to an enhanced prioritization of subjectively important information compared with younger adults. Thus, the present work provides novel insight regarding how younger and older adults may be strategic when choosing to offload information and that under some conditions, older adults may be tuned to the consequences of forgetting subjectively important information.

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Received October 17, 2022
Revision received March 27, 2023
Accepted March 29, 2023 ■