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Optimal Cognitive Offloading: Increased Reminder Usage But Reduced Proreminder Bias in Older Adults

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Research into prospective memory suggests that older adults may face particular difficulties remembering delayed intentions. One way to mitigate these difficulties is by using external reminders but relatively little is known about age-related differences in such cognitive offloading strategies. We examined younger and older adults' ($N = 88$) performance on a memory task where they chose between remembering delayed intentions with internal memory (earning maximum reward per item) or external reminders (earning a reduced reward). This allowed us to distinguish (a) the absolute number of reminders used versus (b) the proreminder or antireminder bias, compared with each individual's optimal strategy. Older adults used more reminders overall, as might be expected, because they also had poorer memory performance. However, when compared against the optimal strategy weighing the costs versus benefits of reminders, it was only the younger adults who had a proreminder bias. Younger adults overestimated the benefit of reminders, whereas older adults underestimated it. Therefore, even when aging is associated with increased use of external memory aids overall, it can also be associated with reduced preference for external memory support, relative to the objective need for such support. This age-related difference may be driven at least in part by metacognitive processes, suggesting that metacognitive interventions could lead to improved use of cognitive tools.

Public Significance Statement

People often use external reminders like calendars or smartphone that alerts to help them remember delayed intentions; however, little is known about whether younger and older adults have different preferences for using these techniques rather than internal memory. Using an experimental task, we found that older adults tended to use reminders more often than younger participants; however, this increase was relatively small compared with their decline in memory ability. Therefore, when compared against the actual need for reminders, younger adults had a greater preference for external memory support than older participants.

Keywords: aging, prospective memory, cognitive offloading, delayed intentions, metacognition

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Data and code to reproduce all analyses, along with the original study preregistration, can be found at https://osf.io/gmrbe/ (Tsai & Gilbert, 2023). An earlier version of this article was posted at https://psyarxiv.com/2cghy/ (Tsai et al., 2023).

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Over the course of an average day, we form many intentions that cannot be immediately executed, such as remembering to pass on a message when you see a particular colleague or to call them at a specific time. The ability to remember deferred intentions and fulfill them at the appropriate time is termed "prospective memory" (PM; Einstein & McDaniel, 1990; Ellis, 1996). PM failures are associated with important real-world implications, such as maintaining health (e.g., forgetting to take medication) and safety (e.g., forgetting to turn off an oven), which may pose a particular challenge for older adults. Moreover, it has been shown that PM failures have a greater impact than retrospective memory on the functional independence of older adults (Hering et al., 2018; Sheppard et al., 2020), and forgetting to perform an intended action at the appropriate future moment is reported as the most frequent memory failure in our everyday life (Haas et al., 2020).

External reminders such as calendars, alarms, and digital devices can play an important role in reducing PM failures in everyday life

(Jones et al., 2021); however, such strategies are not always chosen optimally when one considers that setting a reminder, as well as increasing the likelihood of remembering, also carries a cost in terms of time and effort (Gilbert et al., 2020, 2023). In this study, we aimed to directly compare how optimal younger and older adults are when they make these choices in an experimental task. By understanding age-related differences in reminder usage, this could lead to the development of interventions to improve the fulfillment of PM tasks in older adults.

Prospective Memory and Aging

In contrast to laboratory retrospective memory tasks, where the experimenter typically initiates retrieval, PM tasks pose a high demand on self-initiated processes and offer low environmental support (Craik, 1986). Since the ability to recruit self-initiated processes declines with advancing age, it has been suggested that PM tasks should be particularly sensitive to the effects of aging (Maylor, 1995; McDaniel & Einstein, 2000). Indeed, in laboratory settings, but not necessarily naturalistic ones, younger participants usually outperform older participants on PM tasks (Henry et al., 2004; Kliegel et al., 2008; Zuber & Kliegel, 2020). However, age differences in PM vary substantially across individual studies. Whereas some studies found a significant age-related decline in PM (e.g., Park et al., 1997), other studies revealed similar PM performance in younger and older adults (e.g., Einstein & McDaniel, 1990). One factor that may contribute to discrepant results between laboratory and naturalistic studies is that people typically have the opportunity to use external memory aids in everyday life but not in the laboratory.

Metacognition and Cognitive Offloading

Cognitive offloading—that is, the use of physical action to reduce the cognitive demands of a task—is a common strategy used to help people accomplish PM tasks in daily life (Risko & Gilbert, 2016). For example, people can use diaries, calendars, to-do lists, and digital reminders to help them remember intentions (Gilbert et al., 2023). Recent research has begun to investigate the mechanisms by which individuals decide whether to engage in cognitive offloading to support their PM. Gilbert (2015b) showed that participants with lower confidence in their memory ability tended to use more reminders, regardless of their objective memory ability. Therefore, results indicated that people choose to use reminders based on a metacognitive evaluation of their memory ability, which does not necessarily reflect the actual need for reminders. In addition, Boldt and Gilbert (2019) showed that reminder setting is guided by low confidence even in a situation where the strategy needs to be spontaneously generated rather than explicitly instructed.

To further evaluate the relationship between metacognition and cognitive offloading, Gilbert et al. (2020) developed an "optimal reminders" task in which participants need to balance the benefit of reminders (increase chance of remembering) against a cost (reduced reward). This allowed investigation not only of whether or not individuals choose to set reminders but also of how these choices compare with the optimal strategy for the task. Studies using this paradigm have shown that individuals typically have a proreminder bias, choosing to use external reminders more often than would be optimal (Ball et al., 2022; Engeler & Gilbert, 2020; Gilbert et al., 2020; Kirk et al., 2021; Sachdeva & Gilbert, 2020). This bias is stable over time (Gilbert et al., 2020) and correlates with metacognitive evaluations: individuals who are underconfident in their memory ability tend to show a stronger proreminder bias (Engeler & Gilbert, 2020; Gilbert et al., 2020; Kirk et al., 2021). This bias is also influenced by metacognitive interventions. When individuals are made to feel less confident about their memory ability, this can increase their proreminder bias (Gilbert et al., 2020; though see also Engeler & Gilbert, 2020; Grinschgl et al., 2021).

Aging and Metacognitive Monitoring

Given the evidence that metacognitive processes guide reminder-setting behavior, it is relevant to consider the influence of aging on metacognition. There is considerable evidence that brain regions in prefrontal and parietal cortex which are important for metacognition (Fleming et al., 2012; McCurdy et al., 2013) are also predisposed to aging-related atrophy (Tisserand, 2004). However, behavioral evidence for metacognitive decline in older age is mixed. While some elements of metacognitive functioning may decline with age, other elements may be preserved or even improved (see Castel et al., 2016; Hertzog, 2016, for an overview). This may depend on the type of task, memory domain, assessment method, and so on (McGillivray & Castel, 2017; Siegel & Castel, 2019).

For example, studies investigating judgments of learning (JOLs) have produced mixed results. Bruce et al. (1982) investigated differences in metacognitive monitoring between younger and older people by asking participants to predict how many items they would remember after learning a word list. Younger adults demonstrated greater prediction accuracy (i.e., a smaller difference between the predicted and actual number of recalled words). The two groups predicted a similar number of words but older participants recalled fewer. As a result, older people exhibited overconfidence in their memory performance, which could be interpreted as an age-related metacognitive deficit. However, more recent studies investigating JOLs on the basis of item-by-item predictions have suggested preserved metacognitive monitoring in older participants. Connor et al. (1997) asked participants, after studying each item, to predict whether they would remember it. They found comparable prediction accuracy between younger and older participants. Studies of item-level JOLs have also shown comparable ability of younger and older participants to distinguish remembered versus forgotten items (Devolder et al., 1990; Hertzog et al., 2010).

Also within the domain of PM, the relatively few studies of metacognition and aging have produced mixed results (Kuhlmann, 2019). Devolder et al. (1990) asked participants to predict the likelihood of performing a naturalistic PM task and found older adults displayed better metacognitive judgment. Cauvin et al. (2019) used a laboratory paradigm to evaluate age differences in metacognitive functioning for two components: prospective versus retrospective. Having studied word pairs representing cue–action associations, participants were asked to press a specific button when they noticed one of the cues and then type its associated pair. They provided separate predictions for how likely they would be to press the button (i.e., the prospective component) and how likely they would be to remember the paired word (i.e., the retrospective component). While there were no age differences for the retrospective component, older adults were more overconfident in their performance for the prospective component, which was considered as an age-related deficit. These results suggest that aging has a greater impact on metacognitive monitoring for the prospective component than the retrospective component of prospective memory. This dissociation highlights the importance of distinguishing different aspects of metacognition, which may not be influenced uniformly by aging.

In contrast with the evidence above suggesting that older adults may be more overconfident about their memory ability than younger adults, in a recent study, Scarampi and Kliegel (2021) found that both age groups were similarly underconfident when asked to predict their performance at a prospective memory task. Still, other studies have shown that confidence in one's memory ability tends to decline with age (Dobbs & Rule, 1987). As a result, it might be expected that older adults would be more likely to use external reminders. Consistent with this, it has been suggested that lower confidence in older adults can lead to a volitional avoidance of memory retrieval (Touron, 2015). However, studies investigating self-report of reminder usage in different age groups have produced inconsistent results (Lovelace & Twohig, 1990; Rendell & Thomson, 1999).

Aging and Metacognitive Control

While metacognitive monitoring refers to the ability to evaluate one's ability or performance, metacognitive control refers to the use of this knowledge to influence behavioral strategies such as setting reminders for intentions that might otherwise be forgotten (Boldt & Gilbert, 2022). Appropriate behavioral regulation therefore depends on both aspects of metacognition (Hertzog, 2015). Previous evidence has documented a deficit in older adults' ability to use their memory to access information on which to base their monitoring (Souchay, 2007). There is also evidence for a dissociation between metacognitive knowledge and control during child development. Redshaw et al. (2018) administered the intention offloading task (Gilbert, 2015a) to children aged approximately 7–13 years who were asked to fulfill one or three delayed intentions on each trial and allowed to choose freely between using internal memory and setting reminders. While even the youngest children (<9 years) predicted worse memory performance for three-item than one-item trials, only older children (9 years upward) translated this metacognitive knowledge into the metacognitive control required to selectively set reminders when there were more items to remember.

A small number of studies have so far investigated whether older adults would offset age-related decline in memory ability by setting more reminders (Einstein & McDaniel, 1990; Henry et al., 2012). The findings generally indicated that although the availability of reminders enhanced PM performance, this effect did not interact with age. These results were confirmed by a recent study by Scarampi and Gilbert (2021) employing the intention offloading task (Gilbert, 2015b). Older adults had poorer unaided performance. When they were permitted to set reminders, they were only slightly (and nonsignificantly) more likely to do so, and the performance gap between younger and older adults remained. Therefore, older did not fully compensate for reduced memory capacity by using reminders. In addition, older (but not younger) adults were overconfident about their memory ability. Based on this, Scarampi and Gilbert (2021) concluded that older adults do not necessarily compensate for impaired memory ability and that metacognitive differences between younger and older individuals may account for this, at least in part.

The aim of the present study was to further investigate age differences in reminder setting using the "optimal reminders" paradigm designed by Gilbert et al. (2020). Unlike the paradigm used by Scarampi and Gilbert (2021), which only considers the absolute number of reminders set by participants, this allows a distinction to be made between (a) the absolute number of reminders used by younger versus older adults and (b) their proreminder or antireminder bias, relative to the optimal strategy (see Starns & Ratcliff, 2012, for a related approach, comparing older vs. younger adults against an optimal decision-making strategy). Suppose that older adults set more reminders than younger adults. This could reflect (a) an adaptive compensatory response to a reduced unaided ability to perform the task; (b) a shift in the bias toward using, or avoiding, external reminders; or (c) a combination of the two. We aimed to distinguish these possibilities in the present study.

Based on the analysis of age effects reported by Gilbert (2015a) and the nonsignificant trend found by Scarampi and Gilbert (2021), we made two main predictions. First, we predicted that older adults would set numerically more reminders than younger adults. What about the issue of proeminder versus antireminder bias? The evidence reviewed above suggests that older adults can be overconfident in their prospective memory ability. However, the wider cognitive aging literature is mixed and also provides substantial evidence that older adults tend to avoid internal memory processes (Touron, 2015) and are more reliant on environmental support (Lindenberger & Mayr, 2014) or scaffolding (Zahodne & Reuter-Lorenz, 2019). Based on this evidence, our second main hypothesis was that older adults would show an increased bias toward external reminders, along with an increased propensity to set reminders in general. As shown below, these hypotheses were only partially correct.

Method

Transparency and Openness

We report below how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study. All data and analysis code are available at https://osf.io/gmrbe/. Data were analyzed using R, Version 4.0.0. Before data collection, we preregistered our hypotheses, experimental procedure, and analysis plan (https://osf.io/gmrbe/).

Participants

The final sample consisted of 44 younger participants (mean age: 23.8 years; range: 19–30; 13 male, 31 female) and 44 older participants (mean age: 72.8 years; range: 60–89; 16 male, 28 female). The racial distributions of these groups were not recorded. According to our preregistered plan, a sample of 88 participants was required to achieve 80% power to detect an effect size (Cohen's d) of 0.61 in a two-tailed independent samples t test with an α of 0.05. This effect size was based on the meta-analysis of Uttl (2008), and, more precisely, on the comparison between younger and older participants in the performance of prospective memory paradigms most similar to the present one ("vigilance and event-based tasks"). In order to achieve this sample size, a total of 109 volunteers were tested due to our preregistered exclusion criteria (see below).

Younger participants were recruited from the Institute of Cognitive Neuroscience participant database, while older participants were recruited via flyers distributed by email and around the university campus and local community. Participants provided brief health histories to allow researchers to check inclusion criteria before they were invited to attend. They were excluded if they had history of major neurological or psychological conditions, significant mental or memory problems diagnosed by a doctor, or color blindness. All participants provided informed consent before taking part and the study was approved by the University College London (UCL) Research Ethics Committee (1584/002; neurocognitive mechanisms of attention and memory). Data collection took place in London, United Kingdom, during 2019.

Procedure

Participants were tested individually at the Institute of Cognitive Neuroscience, UCL. They performed the experimental task using the touchscreen of a tablet computer (Samsung SM-T580). Participants were paid according to the points they scored during the task. They received £0.30 for every 100 points, along with a base payment of £8.50 so that the maximum reward was about £10.

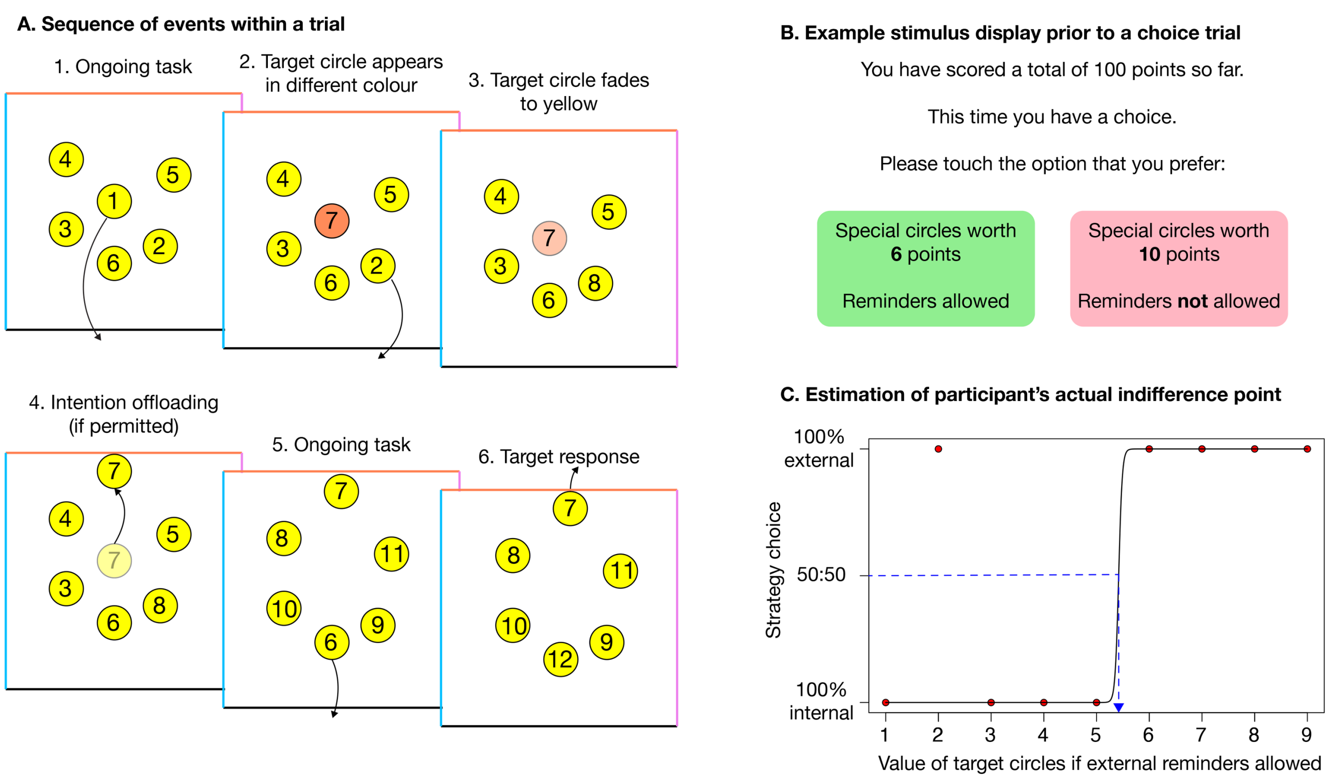
Optimal Reminders Task

See Figure 1 for a schematic illustration of the task. There were three main elements to each trial of the task:

1. Ongoing task: At the beginning of each trial, six yellow circles numbered 1–6 were positioned randomly in a box. Participants were instructed to use their fingers to drag the yellow circles in numerical sequence (1, 2, 3, etc.) to the bottom of the box to make them disappear. Once a circle was removed from the box, a new one appeared in its location to continue the sequence (e.g., after circle 1 was dragged to the bottom of the box, a new one labeled 7 appeared in its place). This continued until 25 circles had been dragged out of the box.
2. Delayed intention task: When new circles appeared on the screen, occasionally they were presented initially in blue, orange, or pink. This served as an instruction for a delayed intention that the circle should be dragged to the blue (left), pink (right), or orange (top) edge when they were reached in the sequence. For example, if number 7 initially appeared in blue, the participant should drag numbers 2–6 to the bottom of the box, then drag number 7 to the left. The initial colors of these target circles only lasted for 2 s, then faded to yellow so that they were identical to the other circles. Therefore, participants needed to remember the colors of target circles and drag them to their respective edges later.
3. Offloading strategy: Participants could depend on their own memory to form internal representations of the delayed intentions or offload them by setting external reminders. They did this by dragging target circles next to the intended edge of the box as soon as they first appeared. This meant that the location of the target circles

Figure 1

Schematic Illustration of the Optimal Reminders Task and Estimation of Participants' Indifference Points



Note. See the online article for the color version of this figure.

served as a reminder of where it should eventually be dragged when it was reached in the sequence.

Within each 25-circle sequence, 10 targets were allocated to the numbers 7–25, spaced as evenly as possible. This means that participants would need to remember multiple delayed intentions simultaneously and it was unlikely that they would remember all of them if the offloading strategy was not allowed. The target circles were allocated randomly to the left, top, and right positions of the box.

Experimental Procedure

Participants first had a short practice of the optimal reminders task relying on their internal memory only. Then the intention offloading strategy was explained and they practiced this strategy until they achieved an 80% accuracy rate. After this, participants made a metacognitive judgment to indicate what percentage of target circles they thought they were able to remember, separately for when they had to use their own memory and external reminders. The instructions were:

> Now that you have had some practice with the experiment, we would like you to tell us how accurately you can perform the task when you do it without using any reminders. Please use the scale below to indicate what percentage of the special circles you can correctly drag to the instructed side of the square, on average. 100% would mean that you always get every single one correct. 0% would mean that you can never get any of them correct.

After participants reported their confidence, they were asked "Now, please tell us how accurately you can perform the task with reminders. As before, 100% would mean that you always get every special circle correct. 0% would mean that you can never get any of them correct."

There were 17 trials in total (each consisting of 25 circles to be dragged, including 10 targets). For the eight even-numbered trials, participants were forced either to use their own memory ("forced-internal" condition) or to use reminders ("forced-external condition"). They alternated between these conditions, with the starting condition randomized. In these trials, they got ten points for each correct target response. In forced-internal trials, all circles were immovable in position except the current item in the sequence, so target circles could not be dragged into reminder locations. In the forced-external trials, participants were required to adjust the position of each new target circle or they were not able to continue with the task.

For the nine odd-numbered trials, participants were given a free choice between earning maximum points (10) for each remembered target using their own memory or a smaller number of points using reminders. The smaller number varied from trial to trial, with the nine possible values from 1 to 9 presented in random order. During each trial, a timer on the screen counted down from 3 min and participants were encouraged to complete each trial before it reached zero. If they did not, a message appeared saying "Out of time. Please go faster." However, this did not prevent them from continuing with the task. Following each trial, participants were told the total number of points they had scored so far. For a demonstration version of the experimental task (including the practice session), please see "https://samgilbert.net/demos/optimalDemo/start.html."

After the experimental task, all participants were administered some further tests in the following order: Beck Depression Inventory (BDI), Montreal Cognitive Assessment (MoCA) Test, National Adult Reading Test (NART), and Raven's Progressive Matrices (RPM)-Form A. BDI and MoCA were adopted to exclude participants with depression or suspected dementia. The cutoff points of the BDI and MoCA were 11 (Suija et al., 2012) and 23 (Luis et al., 2009), respectively. The NART was used to measure crystallized intelligence and the RPM to investigate fluid intelligence (Bilker et al., 2012).

Data Analysis

The following measures were calculated:

1. Self-reported confidence (i.e., predicted accuracy) when using internal memory (Confidence Internal).
2. Mean accuracy from the forced trials using internal memory (Accuracy Internal).
3. Self-reported confidence (i.e., predicted accuracy) when using external reminders (Confidence External).
4. Mean accuracy from the forced trials using external reminders (Accuracy External).
5. Metacognitive bias: The difference between subjective confidence and actual accuracy. This was calculated separately for the internal (i.e., Confidence Internal-Accuracy Internal) and the external (i.e., Confidence External-Accuracy External) conditions.
6. Optimal indifference point (OIP): The target value at which an unbiased individual would be indifferent between using internal memory (earning 10 points per remembered item) or external reminders (earning this number of points per remembered item).

For example, if a participant's accuracy was 60% in forced-internal trials and 100% in forced-external trials, the OIP would be six because the total number of points scored in the internal condition (60% accuracy × 10 points per item) is the same as the external condition (100% accuracy × 6 points per item). Seeing as targets are always worth 10 points in the internal condition, we can derive:

$$\text{OIP} \times \text{AE} = 10 \times \text{AI}. \tag{1}$$

Rearranging, this gives:

$$\text{OIP} = \frac{10 \times \text{AI}}{\text{AE}}. \tag{2}$$

7. Actual indifference point (AIP): The estimated point at which participants were actually indifferent between the two strategies. If this is higher than the OIP, this indicates a bias toward internal memory (because participants would need to be offered a greater amount than the OIP to choose external reminders). If it is lower than the OIP, this indicates a bias toward external reminders (because participants would be using external reminders even when offered a number of points below the OIP). The AIP was calculated by fitting a sigmoid function to the

choice data across the nine trials using the R package "quickpsy" bounded to the range 1–9 and otherwise using default parameters. This allowed us to calculate the value associated with a 50% probability of choosing either strategy, according to this function. This approach does not necessarily require a monotonic relationship between value and strategy choice, for example, if participants accidentally chose an external strategy for one of the low-value choices (see Figure 2). The AIP can be taken as an index of each individual's propensity to use external reminders (low AIP = high number of reminders and vice versa).

8. "Reminder bias": The difference between the OIP and AIP (i.e., OIP minus AIP). A positive value would indicate that the participant set more reminders than would be optimal. A negative value would mean that the participant set fewer reminders than optimal. A participant who had no bias has a score of zero. Note that the reminder bias depends on an individual's own level of memory performance. For example, an AIP of five would indicate a bias toward internal memory for an individual who achieves 40% accuracy using internal memory, assuming that accuracy is 100% with reminders. The same AIP would indicate a bias toward external reminders for an individual who achieves 60% accuracy with internal memory. Therefore, this bias score is relative to each individual's optimal strategy. It is not the same as the overall propensity to set reminders.

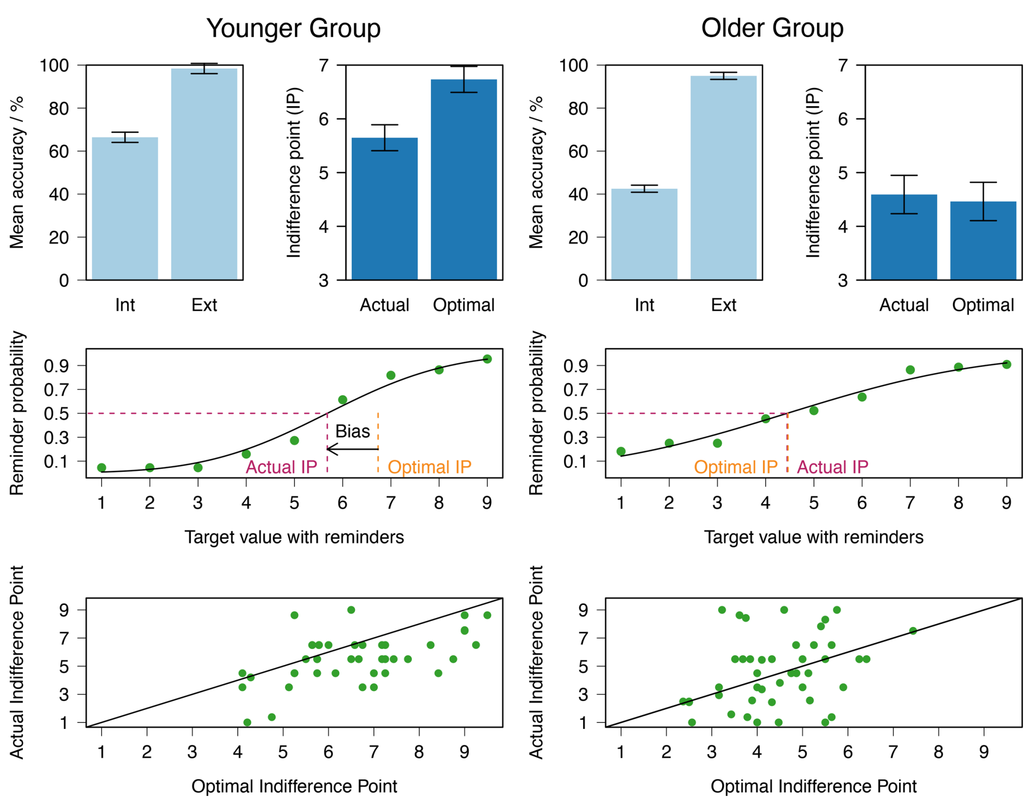
Exclusion Criteria

Participants were excluded if they satisfied any of the following preregistered criteria:

- The cutoff points of the BDI and MoCA were 11 (Suija et al., 2012) and 23 (Luis et al., 2009), respectively.
- Accuracy in the forced-internal condition below 10%.
- Accuracy in the forced-external condition below 70%.
- Negative point biserial correlation between points offered for correct responses with reminders (1–9) and choice of

Figure 2

Results From the Intention Offloading Task: Accuracy and Intention Offloading



Note. OIP = optimal indifference point; AIP = actual indifference point. Data from the younger group are shown on the left and the older group on the right. Top row: light blue: accuracy in the forced-internal (unaided memory) and forced-external (reminder) conditions. Error bars represent within-subject confidence intervals which means $p < .05$ when they do not overlap with each other. Dark blue: actual and OIPs. Middle row: the probability of choosing to set reminders was averaged at every correct target value from 1 to 9 attached to the external strategy in the free-choice trials. The mean of AIP and OIP is also shown. Bottom row: the AIP and OIP of each participant were showed. The diagonal line represents the calibration that the actual choice is the optimal choice. Points below the line indicate a bias toward external reminders and points above the line indicate a bias toward internal memory. See the online article for the color version of this figure.

strategy (0 = own memory, 1 = reminders). This excluded participants who preferentially offloaded when it earned them fewer points, which would suggest random strategy selection behavior. These accuracy and performance-based criteria were based on the same criteria used in previous investigations using the same task (e.g., Kirk et al., 2021).

- Reminder bias score of more than 2.5 *SD*s from the mean of participants in that age group.
- Metacognitive bias with unaided memory more than 2.5 *SD*s from the mean of participants in that age group.

Twenty-one participants were excluded due to our preregistered criteria (https://osf.io/gmrbe/). Seventeen (five younger; 12 older) were removed due to BDI or MoCA scores. Two (one younger; one older) were removed as a result of the negative point biserial correlation. Two younger participants were excluded because their reminder bias score was more than 2.5 *SD*s from the mean. No participant met any of the other exclusion criteria. All analyses reported below produced similar results when conducted on the full sample prior to exclusions (nonsignificant results remained nonsignificant; significant results remained significant). In one case, a previously significant result became marginally significant when the full sample was analyzed; this is highlighted below.

Results

All analyses were conducted in accordance with the preregistered plan, except where noted. There was no significant difference in education duration between younger ($M = 16.9$, $SD = 2.6$) and older ($M = 16.4$, $SD = 4.9$) participants, $t(66.4) = 0.68$, $p = .50$, $d = .15$. RPM scores were higher in younger ($M = 6.3$, $SD = 2.5$) than older ($M = 4.6$, $SD = 1.7$) participants, $t(76.5) = 3.7$, $p < .001$, $d = 0.78$. By contrast, NART scores were higher in older ($M = 37.5$, $SD = 6.5$) than younger ($M = 27.1$, $SD = 5.1$) participants, $t(81) = 8.4$, $p < .001$, $d = 1.78$. These results are consistent with previous research suggesting that healthy older people maintain crystallized intelligence, while fluid intelligence tends to decline (Horn & Cattell, 1967; Nettelbeck & Rabbitt, 1992).

Accuracy at the Delayed-Intention Task

We first investigated accuracy in the forced-internal and forced-external conditions (Figure 3). Accuracy in the forced-internal condition was considerably higher in younger ($M = 66.4\%$, $SD = 17.3$) than older ($M = 42.5\%$, $SD = 11.6$) participants, $t(76.9) = 7.90$, $p < .001$, $d = 1.63$. The forced-external condition also showed a small but statistically significant advantage in the younger ($M = 98\%$, $SD = 3.4$) compared with the older ($M = 95.0\%$, $SD = 5.7$) participants, $t(70.2) = 2.9$, $p < .004$, $d = 0.63$.

Reminder-Setting Behavior

Next, we investigated the total number of trials, out of the nine choice trials, where participants chose to use external reminders. This number was significantly higher in the older ($M = 5$, $SD = 2.2$) than the younger ($M = 3.8$, $SD = 1.8$) group, $t(82.2) = 2.67$, $p = .009$, $d = 0.57$. Relatedly, the AIP was significantly lower in the older ($M = 4.6$, $SD = 2.4$) than the younger ($M = 5.6$, $SD = 1.8$) group, $t(78.5) = 2.32$, $p = .02$, $d = 0.49$. Therefore, older adults used more reminders than the younger adults. The OIP was also significantly lower in the older ($M = 4.5$, $SD = 1.1$) than the younger ($M = 6.7$, $SD = 1.6$) group, $t(77.3) = 7.64$, $p < .001$, $d = 1.63$. This shows that it was optimal for older adults to use more reminders than younger adults.

Reminder Bias

Having shown (a) that it was optimal for older adults to use more reminders than younger adults and (b) that they actually did so, we next investigated the reminder bias, that is, the difference between actual and optimal reminder-setting behavior. The younger group showed a significant proreminder bias, $M = 1.1$, $SD = 1.6$; $t(43) = 4.53$, $p < .001$, $dz = 0.68$; however, there was no significant bias in the older group, $M = -0.1$, $SD = 2.3$; $t(43) = 0.37$, $p = .72$, $dz = 0.06$. Moreover, the proreminder bias was significantly greater in the younger than the older group, $t(75.6) = 2.84$, $p = .006$, $d = 0.61$. These results are not congruent with our initial hypothesis. Rather than an increased proreminder bias in older adults, as we initially predicted, the proreminder bias was actually eliminated in the older group.

Metacognitive Judgments

Older adults predicted lower accuracy with internal memory ($M = 36.4$, $SD = 13.6$) than the younger group, $M = 46.1$, $SD = 17.5$; $t(81.0) = 2.90$, $p = .005$, $d = 0.62$. Both groups were significantly underconfident, relative to their actual accuracy level, younger: $M = -20.4$, $SD = 21.3$, $t(43) = 5.7$, $p < .001$, $dz = 0.85$; older: $M = -6.1$, $SD = 17.0$, $t(43) = 2.37$, $p = .02$, $d = 0.36$. The degree of underconfidence was greater in younger than older participants, $t(77.7) = 3.2$, $p = .002$, $d = 0.69$.

Older adults also predicted lower accuracy when using external reminders ($M = 74.5\%$, $SD = 17.5$) than the younger group, $M = 92.0\%$, $SD = 9.4$; $t(65.9) = 5.8$, $p < .001$, $d = 1.25$. Again, both groups were significantly underconfident, younger: $M = -5.9$, $SD = 9.3$; $t(43) = 4.2$, $p < .001$, $dz = 0.64$; older: $M = -20.4$, $SD = 17.1$; $t(43) = 7.92$, $p < .001$, $d = 1.19$. However, this time, the degree of underconfidence was greater in older than younger participants, $t(66.2) = 4.95$, $p < .001$, $d = 1.05$.

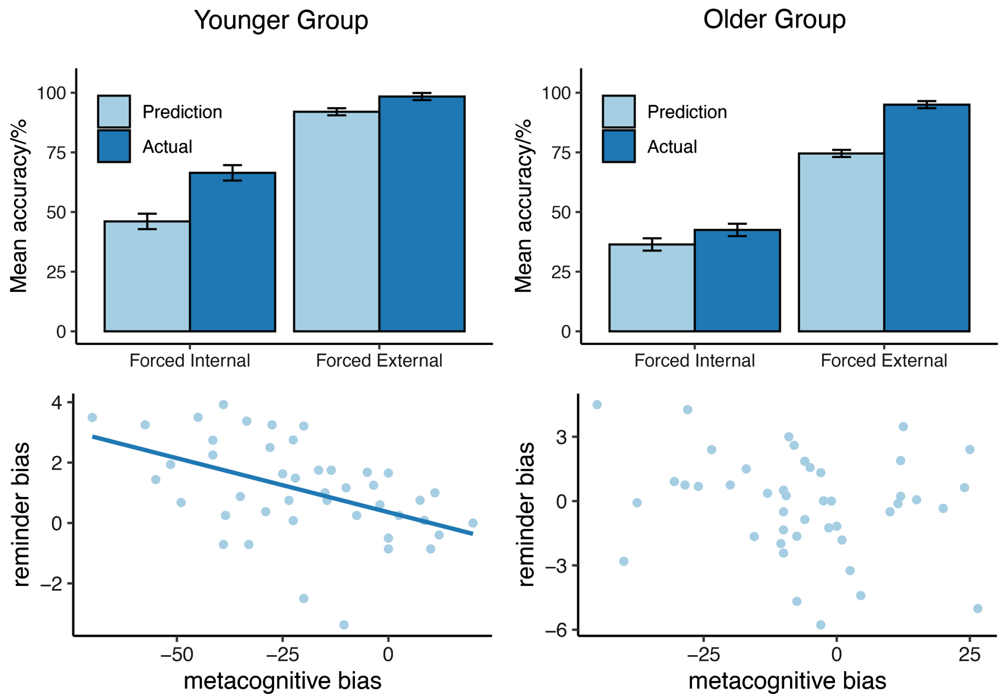
We investigated the correlation between internal metacognitive bias and reminder bias separately in the two groups. The expected negative correlation was obtained in younger individuals ($r = -.34$, $p < .02$), showing that participants who were more underconfident in their memory ability tended to exhibit a greater proreminder bias (this correlation was only marginally significant when the full pre-exclusion sample was analyzed: $r = -0.24$, $p = .08$). However, the correlation was not significant in the older group ($r = -.21$, $p = .17$).

Additional Nonpreregistered Analyses

This section reports some exploratory tests conducted in addition to the preregistered ones described above. This allows us to better characterize the pattern of results in each group, as well as perform direct statistical comparisons between younger and older participants. First, we investigated the correlation between AIP and OIP separately in the two groups. Both correlations were significant (younger: $r = .56$, $p < .001$; older: $r = .32$, $p = .03$). This shows that

Figure 3

Results From the Intention Offloading Task: Metacognitive Measures



Note. Data from the younger group are shown on the left and the older group on the right. Upper row: actual accuracy and predicted accuracy in the forced-internal and forced-external (predicted accuracy: light blue; actual accuracy: dark blue) conditions. Error bars represent within-subject confidence intervals, which means $p < .05$ when they do not overlap with each other. Lower row: actual accuracy and predicted accuracy in the forced-internal (unaided memory) and forced-external (reminder) conditions. Error bars represent within-subject confidence intervals, which means $p < .05$ when they do not overlap with each other. The relationship between the reminder bias and metacognitive bias about unaided memory is revealed. While the reminder bias was correlated with the metacognitive error in the younger group, it was not observed in the older group. See the online article for the color version of this figure.

individuals who had a greater need for reminders (lower OIP) also tended to set them more often (lower AIP). This suggests that individuals in both groups used metacognitive judgments to influence their reminder-setting behavior.

Second, we investigated accuracy in the forced-internal and forced-external conditions in a mixed 2 × 2 analysis of variance with factors age and condition (the significant effects of age, separately for each condition, are already reported above). There were significant main effects of age, $F(1, 86) = 55.72, p < .001, \eta_p^2 = .39$, and condition, $F(1, 86) = 809, p < .001, \eta_p^2 = .9$, along with a significant interaction, $F(1, 86) = 50.4, p < .001, \eta_p^2 = .37$. This interaction shows that the age-related impairment found when participants had to rely on their own memory ability (forced-internal condition) was significantly attenuated when participants could rely on external reminders instead (forced-external condition).

Third, we directly compared the degree of underconfidence in the forced-internal versus forced-external conditions. The younger group was significantly more underconfident about the forced-internal than the forced-external conditions, $t(43) = 4.04, p < .001, dz = 0.61$. Another (statistically equivalent) way of describing this result is that younger adults predicted a greater improvement in accuracy as a result of using reminders ($M = 46.0\%$, $SD = 18.3$) than the actual improvement ($M = 31.5\%$ $SD = 16.4$). The older group showed the reverse pattern. They were significantly more underconfident in the forced-external than the forced-internal conditions, $t(43) = 4.22, p < .001, dz = 0.64$. Thus, the predicted benefit of reminders in older participants ($M = 38.1\%$, $SD = 19.7$) was less than the actual benefit ($M = 52.5\%$ $SD = 10.8$). Therefore, whereas younger adults significantly overestimated the benefit of reminders, older adults significantly underestimated the benefit.

Finally, seeing as there was a significant correlation between metacognitive bias and reminder bias in the younger but not the older group, we directly compared these correlations using a Fisher r-to-z transformation. The result showed that there was no significant group difference, $z(41) = 0.64, p = .52$.

Discussion

This study was designed to investigate how younger and older participants differ in their decisions about offloading strategies for delayed intentions. Whereas previous work compared the absolute number of reminders used by younger and older participants (Scarampi & Gilbert, 2021), this study examined how *optimal* older adults are in a paradigm where they need to balance the cost against the benefit of using reminders. Results supported previous laboratory studies (Henry et al., 2004; Uttl, 2008) that have shown an age-related decline in PM task performance. Consequently, it was optimal in our task for older adults to use more reminders than younger. We found that older participants indeed set numerically more reminders than the younger group. However, whereas younger adults had a proreminder bias relative to the optimal strategy, replicating previous results (Ball et al., 2021; Engeler & Gilbert, 2020; Gilbert et al., 2020; Kirk et al., 2021), this bias was significantly reduced in the older group, whose reminder-setting behavior did not differ significantly from the optimal strategy. Therefore, we found opposite results depending on whether one considers (a) the absolute number of reminders (increased in older adults) or (b) the proreminder bias relative to the optimal strategy (decreased in older adults). This shows that even in a situation where older adults make greater use of environmental cognitive support, they may nevertheless show a reduced preference for such support in comparison with younger adults. Consistent with this finding, Henry et al. (2012) and Scarampi and Gilbert (2021) found that older adults do not necessarily compensate for impaired memory performance when a reminder-setting strategy is available. We note, however, that older adults' reduced preference for external reminders in the present study made their offloading strategies *more* optimal in comparison with the proreminder bias shown by younger adults.

The second aim of this study was to explore younger and older adults' metacognitive judgments about their performance. Younger participants were particularly underconfident about their ability to perform the task with internal memory and only slightly underconfident about their accuracy with external reminders. This means that they overestimated the benefit of reminders: the predicted difference between accuracy with versus without reminders was greater than the actual difference. This pattern was reversed in older adults who were particularly underconfident in their ability with reminders but only slightly underconfident in their ability with internal memory. Therefore, older adults underestimated the benefit of external reminders. Although both younger and older participants achieved near-ceiling accuracy when they used reminders, older participants were considerably less confident in their performance when they used this strategy. This contrasting pattern between the two groups, with younger adults overestimating and older adults underestimating the benefit of reminders, could potentially account for the shift in behavioral strategies, with only the younger participants showing a proreminder bias. Consistent with this metacognitive account of offloading strategies, we found that individual differences in younger adults' metacognitive under- or overconfidence were significantly correlated with their proreminder or antireminder bias, replicating an effect seen in previous studies (Ball et al., 2021; Gilbert et al., 2020; Kirk et al., 2021). This correlation was nonsignificant in the older group. However, the nonsignificant trend in the older group was in the same direction as the younger group, and the two correlations were not significantly different from each other, so it is not possible to draw strong conclusions from this.

While younger adults were highly underconfident about their unaided memory ability, older adults were better calibrated. This upward age-related shift in confidence, relative to actual performance, is consistent with other studies demonstrating increased overconfidence in older participants (Bruce et al., 1982; Cauvin et al., 2019; Connor et al., 1997; Scarampi & Gilbert, 2021; Soderstrom et al., 2012). The upward shift could potentially be explained by a failure to update metacognitive beliefs in line with an age-related decline in cognitive ability (cf. Knight et al., 2005 for a related phenomenon in the context of brain injury; Souchay, 2007 in the context of dementia). This could explain the failure of older adults to fully compensate for impaired memory for intentions when a reminder-setting strategy is permitted (Scarampi & Gilbert, 2021). Consistent with this, in a study of prospective memory in real life, Hertzog et al. (2019) found that older people usually expected themselves to remember important PM tasks, relying highly on unaided memory, and did not view external strategies as a compensatory aid for memory decline. The practical implication of these findings is that cognitive offloading strategies could be optimized by designing metacognitive interventions that improve individuals' awareness of their true level of cognitive ability. Previous studies have suggested that metacognitive interventions can influence offloading strategies, although results have been mixed (Engeler & Gilbert, 2020; Gilbert et al., 2020; Grinschgl et al., 2021). This could particularly apply to older adults who may otherwise fail to accumulate sufficient feedback to regulate their metacognitive beliefs (Touron & Hertzog, 2014). It could also be particularly relevant to the domain of delayed intentions, where individuals decide whether or not to offload intentions some time before the intended behavior. This can lead to a long lag between the time at which a strategy is implemented and the time at which an individual can detect whether or not the strategy was effective. As a result of this long time-lag, feedback from task performance may fail to reliably update the metacognitive knowledge used for strategy selection.

Although older adults underestimated the benefit of reminders in this study, their offloading decisions were congruent with the optimal strategy. This pattern of results may appear somewhat surprising. If individuals selected offloading strategies based only on their metacognitive judgments, which underestimated the benefit of reminders, an antireminder bias would be predicted. Seeing as no such antireminder bias was observed, this suggests that one or more additional factors, other than metacognitive judgments, contributed to strategic offloading decisions. One potential factor that has been highlighted (Gilbert et al., 2022) is that individuals may prefer external reminders as a way of avoiding the cognitive effort associated with internal memory. Consistent with this, Sachdeva and Gilbert (2020) found that the proreminder bias was reduced when participants had a financial incentive to behave optimally, which was hypothesized to increase participants' willingness to expend cognitive effort on the task.

While the present results are consistent with the view that older adults also choose to use external reminders as a means of avoiding cognitive effort, this tendency might be reduced if the act of setting reminders is itself seen as effortful. This possibility is congruent with previous research (Hertzog et al., 2012; Lineweaver et al., 2018) showing that older people choose strategies according to both their perceived difficulty and effectiveness, while younger people tend to consider effectiveness predominantly. Similarly, Hertzog et al. (2017) suggested that older people tended to use rote repetition rather than switching to more effective strategies due to the cognitive effort involved in switching strategies. Although intention offloading decreases cognitive effort as a result of removing the requirement to maintain an internal representation of intended behavior, older people may consider the additional reminder-setting behavior to be more effortful, for example, due to the requirement to switch away from the ongoing task to physically set a reminder. Future research could investigate this factor by explicitly manipulating the effort associated with reminder setting.

Limitations of This Study

We note three main limitations of this study that could be addressed in future research. First, it is unclear to what extent the differences we observed between younger and older participants could reflect motivational effects, which could derive from differing reasons for taking part in the research to begin with (Ryan & Campbell, 2021). While we equalized the incentive structure of the task by using an explicit point system which determined participants' payment at the end of the experiment, the effect of this could have differed between younger and older participants. Previous research has shown that financial reward can improve younger adults' performance significantly (Aberle et al., 2010; Honeywell et al., 1997; Shah et al., 1998; Shum, 2004); however, the effect on older people is less clear (Birkhill & Schaie, 1975; Strayer & Kramer, 1994; Touron et al., 2007). Therefore, it would be useful to investigate how far the effects reported here generalize across different tasks with a variety of incentive structures.

Second, our older participants were relatively well-educated (mean: 16 years), so the results may not generalize to the older population as a whole. The older participants in this study may potentially have chosen unaided memory because they were confident of their memory abilities or believed that staying mentally active helped to prevent cognitive decline. It would be helpful to investigate whether similar results hold across different levels of education and/or beliefs about the benefits of mental activity.

Finally, it is unclear how far age differences in cognitive offloading strategies are (a) domain general, (b) relate to specific aspects of cognition such as prospective memory (e.g., due to age differences in the prospective and/or retrospective components of prospective memory), or (c) are even more fine grained than that. For example, results could potentially differ depending on whether reminder setting is performed via a digital device or a more traditional approach such as written notes. Several studies propose that older people tend to avoid modern technology (Chen & Chan, 2014; Oostrom et al., 2013). Therefore, the impact of attitudes toward technology, and the specific mechanism of intention offloading, could potentially play an important role in the age differences reported here; however, this is ultimately an empirical question.

Conclusions

We report four main findings in the present study. First, older adults were significantly less likely than younger adults to remember delayed intentions when they used internal memory. Second, when they were given the option to set external reminders, older adults did so more often. Third, the age-related decline in memory performance was substantially reduced but not eliminated, when reminders were used (see also Scarampi & Gilbert, 2021, for a similar result). The main novelty of this study was that we used a method that distinguishes whether increased reminder setting in older adults reflects (a) an adaptive response to impaired unaided ability versus (b) a difference in individuals' preference toward using internal memory versus external cognitive tools. Despite older adults' increased use of reminders overall, their bias toward reminders relative to the optimal strategy was reduced. Therefore, the increased use of reminders in older adults was attributable to their greater need for external memory support rather than an increased proreminder bias. In contrast to the view that aging is characterized by an increased preference for environmental cognitive support (Lindenberger & Mayr, 2014), our results show that in some situations, older adults have a *reduced* preference for external cognitive support when one takes into account their level of performance when such support is not available. These results may be attributable to age-related differences in metacognitive evaluations. Therefore, we suggest that metacognitive interventions could be an effective means for optimizing individuals' use of cognitive tools across the lifespan.

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