



Younger and older adults' prospective memory: the role of delay task difficulty

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ABSTRACT

There is mixed evidence on the impact of delay task difficulty on prospective memory (PM) performance and little research has examined this among older adults. The present study examined younger ($N = 60$) and older ($N = 57$) adults' prospective memory (PM) performance after completing an easy or difficult Raven's matrices task. To assess whether delay difficulty impacted how often participants thought about their PM intention, participants were asked to report on what they thought about during the delay task itself and retrospectively after all tasks were completed. Younger adults outperformed older adults on the PM task; however, delay task difficulty had no impact PM for either age group. Reports of thinking about the intention during the delay task differed by age group depending whether they were online or retrospective, however, overall greater reports of thinking about the intention was positively associated with PM performance.

ARTICLE HISTORY

Received 30 September 2019
Accepted 27 January 2020

KEYWORDS

Prospective memory;
younger adults; older adults;
delay task difficulty; aging

There are daily occurrences where adults need to remember to carry out a behavior at a later time or event (i.e., prospective memory: PM; Einstein & McDaniel, 1990). For instance, one may need to remember to attend an appointment in the afternoon, take medication before a meal, or bring an important document to work. Given that these day-to-day intentions can be important for either work or school success, health, or can help with overall daily functioning, forgetting to carry out these desired behaviors can be problematic. Indeed, the consequences of declining PM may be particularly meaningful for older adults who may have increasing health concerns, thereby needing to rely frequently on their PM to take medications or attend appointments. Thus, it is of interest to examine factors that facilitate older adults' PM. Given that there is often a delay between setting an intention to do something and subsequently carrying out that intention, the events that transpire during that delay may impact one's success in remembering to perform the desired behavior. In particular, the extent to which one taxes their cognitive resources during the delay may impact the ease with which one remembers their future intention after the delay period.

There is a breadth of experimental research examining adults' PM. To measure PM in a laboratory setting, participants are typically given an intention or instruction for a given task, then they complete a delay task, and then they complete the task with their specific PM intention or instruction embedded within the task (Einstein & McDaniel, 1990). For

example, participants may be told that they will be completing a lexical decision task where they must decide if words are real or not, but that if they see an animal word, they should press the 9-key (i.e., the PM intention). Participants would then complete a delay task prior to completing the target PM task (where they would need to recall that when they see the PM cue (animal word) they are to press the 9-key).

Although results are not entirely consistent, several studies have found an age-related decline in PM in laboratory testing (e.g., Cherry et al., 2001; Dobbs & Rule, 1987; Kidder, Park, Hertzog, & Morrell, 1997; Kliegel, Jäger, & Phillips, 2008; Mantyla & Nilsson, 1997; Maylor, 1993, 1996; McDaniel & Einstein, 2007; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; West & Covell, 2001; but see Einstein & McDaniel, 1990; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Rendell & Craik, 2000). More specifically, PM studies can assess time-based PM (participants are to recall their intention at a certain time) or event-based PM (participants are to recall their intention in response to an event or cue). Age-related declines have been reported across both time-based and event-based PM tasks; however, greater inconsistencies have been found across event-based PM studies, warranting further investigation (Henry, MacLeod, Phillips, & Crawford, 2004).

It has been proposed that successful PM requires self-initiated attention, monitoring, and retrieval, and such skills tend to decline with age (Craik, 1986; Smith & Bayen, 2006). In line with this, some experimental PM tasks rely more on this effortful or strategic processing and have shown greater age-related declines compared to PM tasks that require more spontaneous processing (Henry et al., 2004; Kliegel et al., 2008; Uttl, 2011). More specifically, when a PM task presents a *focal* PM cue that elicits the same processing demands for the PM targets and ongoing task targets (e.g., press a button when you see a specific word while classifying words), retrieval of the PM intention relies on more spontaneous processing that is greater preserved with age (Henry et al., 2004; Kliegel et al., 2008; McDaniel & Einstein, 2000; McDaniel & Einstein, 2007; Mullet et al., 2013; Shelton et al., 2011; but see Uttl, 2011). In contrast, when a PM task presents a *non-focal* PM cue that requires different types of processing for the PM and ongoing targets (e.g., press a button when you see a specific syllable embedded in a word while classifying words), successful retrieval of the PM intention relies on more effortful, strategic processing that shows greater age-related declines (Henry et al., 2004; Kliegel et al., 2008; Mullet et al., 2013; Shelton et al., 2011). Extant literature suggests that there is a significant age-related decline in PM performance on non-focal PM tasks, but the relation between focal PM tasks and aging has been less consistent (Henry et al., 2004; Kliegel et al., 2008; Uttl, 2011).

One factor that may contribute to inconsistencies in PM studies is that the nature of the delay task can impact the success of carrying out one's PM intention. More specifically, manipulating the cognitive demands of the delay task can impact subsequent PM performance. It has been proposed that a delay task with lower cognitive demands may enhance PM and reduce the age-related decline seen in PM. However, results demonstrating the impact of delay difficulty are quite inconsistent (Brandimonte & Passolunghi, 1994; Cook, Ball, & Brewer, 2014; Mahy, Schnitzspahn, Hering, Pagobo, & Kliegel, 2018; Roffler, Willoughby, & Beussink, 2014; Shelton et al., 2013, 2011), and few studies have been conducted with older adult samples (Shelton et al., 2011).

In the first study to examine the effect of cognitive depletion during the delay, aging, and PM, Shelton et al. (2011) examined the effect of delay task difficulty (easy vs. hard versions of the Stroop task) on older adults' PM across focal and non-focal PM tasks. It was proposed that a challenging delay task may be particularly damaging to older adults' PM prior to a non-focal PM task as their self-control resources that would be needed to strategically attend to the non-focal PM cues may have been depleted during the demanding delay task (Baumeister & Heatherton, 1996). Indeed, Shelton et al. found that older adults in the difficult delay condition had poorer PM, but only if this occurred prior to a non-focal PM task that would require more strategic processing (compared to a focal PM task) and were categorized as an "old-old" (71–80 years) rather than "young-old" participant (61–70 years). Thus, delay task difficulty impacted PM performance only when using non-focal PM cues, suggesting that the spontaneous processing needed for focal PM cues may be less affected by prior resource depletion. Further, these effects were limited to the old-old participants, suggesting that resource depletion effects prior to a PM task requiring strategic processing may be particularly detrimental to those with more limited cognitive resources to begin with. Notably, in a similar experiment conducted on younger adults (Shelton et al., 2013), PM performance did not differ as a function of delay Stroop difficulty, suggesting that younger adults' PM can withstand prior taxing of cognitive resources.

It is possible that there are additional explanations, beyond cognitive resource depletion, that might help to explain the effects of delay task difficulty on subsequent PM performance. For instance, the level of attention required for the delay task may alter the extent to which participants engage in mind wandering and can think about their PM intention (Hicks, Marsh, & Russell, 2000; Mahy et al., 2018). That is, tasks that require less focused attention might allow for more opportunities to mind wander where individuals may start thinking about the PM intention and preparing for the subsequent PM task. To test this idea, Mahy et al. (2018) examined younger adults' PM after a difficult (Raven's Matrices; Raven, 1941) or easy (categorizing items as living or non-living) delay task. Importantly, after the delay and PM tasks, participants were asked to report on how often they thought about the PM intention during the delay task to measure thinking about the PM intention as a potential mechanism for the relation between delay task difficulty and PM performance. Counterintuitively, Mahy and colleagues found that participants had better PM after the difficult delay task compared to the easy delay task, and that this improved performance was because the difficult task allowed for greater mind wandering and refreshing of one's PM intention. This study provided insight into how the nature of the delay task can influence the extent to which participants think about their PM intention during the delay period, which, in turn impacts PM.

There are several limitations of Mahy and colleagues' study, however, that need further investigation. Given that the difficult and easy delay tasks were separate tasks entirely, delay task difficulty was confounded with task type. That is, although the difficult task was more cognitively challenging, the nature of the difficult Raven's matrices also made it much slower-paced compared to the cognitively simple, but rapid pace of the easy categorization task. Mahy and colleagues proposed that it may have been the slow and effortful nature of the Raven's task that allowed for participants' minds to wander to the PM intention, whereas the living/non-living categorization task was so fast-paced that participants did not have the time to refresh their PM intention. Alternatively, Mahy et al.

acknowledged that it is possible that these results were driven by the content of the tasks. As the easy task had greater verbal processing demands (labeling and categorizing items) compared to the abstract patterns presented in the difficult task, this verbal processing may have interfered with participants' ability to rehearse their verbal PM intention. Testing PM after the same task that varies in difficulty level will eliminate the confound of different delay task content and extend these findings. Moreover, as this was the first study to experimentally examine participants' reflections on what they thought about during the delay task, continued research is needed to explore this and how thought patterns during various delay tasks may change with age.

The present study seeks to build upon Mahy et al. (2018) study in three ways. First, as previously outlined, in Mahy et al. (2018), the easy and difficult delay task conditions differed in the level of task difficulty but also in task type. In the present study, the same task was used across the easy and difficult conditions, such that participants in the easy condition received a series of easy Raven's matrices and those in the difficult condition received a series of difficult Raven's matrices. Second, to our knowledge, no research has explored what older adults think about during the delay task. Given that older adults have been shown to engage in less mind wandering (Jackson & Balota, 2012; Krawietz, Tamplin, & Radvansky, 2012; Reese & Cherry, 2002), the effect of task difficulty on one's PM thoughts and subsequent PM may differ between younger and older adults. Thus, the present study extended previous research by assessing what older adults report thinking about during the delay interval. Third, in addition to asking participants to retrospectively report on if and how often they thought about the PM intention during the delay task, we asked participants at three-time intervals during the delay task to tell the experimenter what they were thinking about. Given that retrospective reports may be influenced by one's performance (i.e., greater success on the PM task may implicitly encourage participants to report a greater number of times that they thought about the PM intention) and can be less accurate than concurrent reporting (Smallwood & Schooler, 2006), this method of reporting in real-time during the delay may be an effective strategy to capture participants' thought patterns.

The current study

The present study examined the effect of delay task difficulty on younger and older adults' PM performance. In addition, we explored what participants were thinking about during the delay task to test if the difficulty level of the delay task impacted the extent to which one thought about their PM intention during the delay, and if this impacted subsequent PM performance. Given that difficult delay tasks have been shown to deplete older adults' but not younger adults' cognitive resources (Shelton et al., 2013, 2011), we predicted that the effect of delay task difficulty on PM would differ across younger and older adults. Based on Mahy et al. (2018), where participants reported thinking about their PM intention more often during a slower paced and difficult delay task, we expected that younger adults would show superior PM performance after the difficult task compared to the easy task and that those in the difficult condition would report greater rates of thinking about the PM intention during the delay. Although the present study differs from Mahy et al. in that the delay tasks only differ in difficulty level (and not additional task features such as

verbal demands), we expected that our difficulty manipulation would still impact pacing (as with Mahy et al.), allowing participants in the difficult condition to work at a slower pace, thereby possibly providing them with more opportunities to pause and reflect on their PM intention. Of note, we speculated that if Mahy et al.'s PM differences were due to the nature of the tasks, rather than pacing, then we may expect our younger adult sample to show superior PM (and more frequent PM thought reports) after the easy delay as they may experience less cognitive resource depletion or to show no difference across the delay task conditions as young adults' PM is not always affected by prior resource depletion (Shelton et al., 2013). On the other hand, given that older adults' PM tends to be more greatly affected by delay task difficulty (particularly for old-old adults; Shelton et al., 2011) and they have lower rates of mind wandering in general (Jackson & Balota, 2012; Krawietz et al., 2012; Reese & Cherry, 2002), we predicted that the lower cognitive demands within the easy task would help facilitate their PM compared to the difficult condition. In addition, we expected that older adults would think about the PM intention more often in the easy condition compared to the difficult condition because the difficult condition may overload their already more limited cognitive resources.

Method

Participants

Sixty-six younger adults (56 females; $M_{\text{age}} = 19.62$ years, $SD = 1.71$, range = 18–23) and 67 older adults (52 females; $M_{\text{age}} = 71.75$ years, $SD = 6.58$, range = 60–85) participated in the study. A total of 16 participants (6 younger adults; 10 older adults) were excluded due to: participant confusion during the PM task ($N = 8$), technical difficulties ($N = 4$), missing data on the MoCA ($N = 3$), and experimenter error ($N = 1$). The final sample consisted of 60 younger adults (51 females; $M_{\text{age}} = 19.65$, $SD = 1.72$, range = 18–23) and 57 older adults (46 females; $M_{\text{age}} = 71.79$, $SD = 6.57$, range = 60–85). Participants were randomly assigned to one of two experimental conditions that differed in the difficulty level of the delay task: easy delay task or difficult delay task. The average age of participants did not significantly differ across these two conditions for younger $t(58) = 1.44$, $p = .155$ or older adults $t(55) = .404$, $p = .688$. See Table 1 for participant characteristics presented by age group and difficulty delay condition.

All younger adults were current undergraduate students at a medium sized university and thus they had all completed high school as their highest level of education. For the highest level of education obtained by older adults, approximately 60% had started or completed a college or university degree, 23% had completed a post-graduate degree, 15% completed high school, and 1% did not complete high school. Younger adults (77% Caucasian, 10% East Asian, 6% South Asian, 5% African-American, 2% Latin American) and older adults (96% Caucasian, 2% East Asian, 2% Latin American) were predominantly Caucasian. All participants provided informed consent prior to participating in the study. Younger adults were offered 1.0 research credit for a course requirement and older adults were offered the opportunity to win a \$50 gift card for their participation.

Table 1. Participant characteristics and means and standard deviations for performance on the Raven's matrices (Delay task), lexical decision task (Ongoing task), and prospective memory task by age group and condition.

	Younger Adults		Older Adults	
	Easy <i>N</i> = 30	Difficult <i>N</i> = 30	Easy <i>N</i> = 29	Difficult <i>N</i> = 28
Age	19.33 (1.49)	19.97 (1.88)	71.45 (5.88)	73.25 (6.67)
% Female	87	83	79	79
MoCA	26.73 (2.82)	26.90 (2.64)	26.86 (2.63)	27.22 (2.21)
Shipley Vocabulary	26.80 (3.36)	27.63 (3.63)	33.79 (4.64)	34.74 (3.16)
Raven's Matrices accuracy	0.91 (0.73)	0.28 (0.14)	0.84 (0.12)	0.25 (0.16)
Raven's Matrices reaction time	2911.72 (570.46)	15,997.68 (9428.33)	7546.46 (3085.40)	26,320.05 (19,815.91)
Number of Raven's Matrices completed	69.73 (38.19)	47.30 (35.61)	47.48 (20.48)	16.86 (9.47)
Lexical decision task accuracy	0.79 (0.70)	0.80 (0.08)	0.89 (0.05)	0.90 (0.05)
Lexical decision task reaction time	1397.71 (329.36)	1417.99 (290.25)	1786.91 (355.15)	1832.70 (607.47)
Prospective memory accuracy	0.59 (0.40)	0.50 (0.38)	0.44 (0.43)	0.34 (0.32)
Prospective memory reaction time	1374.31 (283.74)	1391.39 (332.95)	1888.82 (450.47)	1967.56 (616.80)

Reaction times (ms) were only calculated for accurate trials. Accuracy rates (for delay, prospective memory, and lexical decision tasks) represent the proportion of correct trials.

Procedure and materials

The experiment was conducted individually in a quiet room with a researcher. All computer tasks were conducted through PsychoPy (version 1.85; Peirce, 2007) on a 24-inch desktop computer. All instructions appeared on the screen for participants and the experimenter read the instructions out loud throughout the study. Prior to the experiment, participants were randomly assigned to an easy or difficult delay task condition within their age group.

First, participants completed the instruction and practice phase of the lexical decision task (ongoing task). Participants were told that they would see a word appear on the screen and they should press '1' if they thought the word was a real word and press '2' if they thought the word was not a real word. Participants completed five practice trials where they were given feedback on whether their response was correct or incorrect. Participants were then presented with the PM instruction that if they saw an *animal* word they should press '9' instead of making the word decision (i.e., pressing '1' or '2'). The experimenter then asked participants to state what they were required to do in this task (i.e., press '1' for a real word, press '2' for a non-word, and press '9' for an animal word). If participants did not report all three rules of the task, the experimenter reminded the participants of the rules and asked them to re-state all the rules.

After confirming participants' understanding of the rules, participants began the delay task (Raven's matrices; Raven, 1941), for which they saw an image of a pattern and were asked to select the picture that completed the pattern. Participants assigned to the easy delay task were presented with easy Raven's matrices (18 of the easiest matrices) and participants assigned to the difficult delay task were presented with difficult matrices (18 of the hardest matrices). Each pattern remained on the screen until a response was made; however, participants were instructed to respond as quickly and as accurately as possible. Accuracy and response times were calculated. While participants were completing the Raven's matrices, three thinking probes appeared after one minute, two minutes, and

three minutes. At each time point, after the participants made their matrix response, a question appeared on the screen asking the participants to “please turn to the experimenter and tell her what you are thinking about right now”. The experimenter wrote down participants’ responses. The sessions were audio taped in the event that the experimenter needed to verify a participant’s response. After the participant responded, they were instructed to press the space bar to continue with the task. The delay task ended automatically after four minutes. Responses to the thought probes were coded into one of three categories: (1) thoughts about the PM intention (pressing ‘9’ for animal words), (2) thoughts about the current task (solving patterns), and (3) off-topic or mind wandering thoughts (e.g., thinking about what to eat for dinner). Of particular interest was the number of times that participants reported thinking about the PM intention.

After the Raven’s matrices were completed, participants were told that they would now complete the lexical decision task. The experimenter reminded participants that they should press ‘1’ if they thought the word was a real word and press ‘2’ if they thought the word was not a real word. Participants were not reminded of the PM intention to press ‘9’ if the word was an animal word. The words/non-words remained on the screen until participants made their responses; however, they were instructed to respond as quickly and as accurately as possible. We used the same task as a prior study (Mahy et al., 2018) where 100 words and pseudowords were randomly selected from the English Lexicon Project (Balota et al., 2007). All words were presented in the same order across participants and four additional animal words (penguin, lizard, chimpanzee, and goose) were presented as the 25th, 50th, 75th, and 100th words as the PM target trials. PM accuracy was calculated as the proportion of times that participants remembered to press ‘9’ for the animal words and reaction times were calculated for accurate trials only. Accuracy on the ongoing task trials (correctly identifying which words are real) was calculated, as was reaction time for accurate trials only.

Upon completion of the lexical decision task, participants were asked to state what they were supposed to do in the task (i.e., press ‘1’ for a real word, press ‘2’ for a non-word, and press ‘9’ for an animal word) to verify understanding of the task. If participants did not state the PM instruction to press ‘9’ for animal words, the experimenter asked up to three follow-up questions in an attempt to retrieve this response: (1) What were you supposed to do in the lexical decision task? (2) Was there something else you had to do in the lexical decision task? And (3) What were you supposed to do when you saw an animal word? If a participant could not remember the PM instruction after these follow-up questions, they were excluded from the experiment ($N = 1$). The experimenter then provided participants with a questionnaire to complete based on their experience during these tasks. Participants were asked: (1) if they thought about pressing ‘9’ for the animal word while they were completing the pattern task (Raven’s matrices), (2) how many times they thought about pressing ‘9’, and (3) if the intention to press ‘9’ for animal words was always present in their mind. Participants were also asked to rate how tired they felt, their level of interest in the Raven’s matrices, and their level of interest in the lexical decision task (on scales from 0 to 10).

Finally, we administered cognitive and vocabulary assessments to examine cognitive differences among younger and older adults, as well as to use them as control variables in our analyses. All participants completed the Montreal Cognitive Assessment (MoCA, version 7.2 alternate version; Nasreddine et al., 2005) to assess general cognitive functioning. Specifically, this task measured visuospatial skills (e.g., draw a clock), naming (e.g., label this animal), memory (e.g., please remember this list of words), attention (e.g., tap

your hand on the table each time I say the letter “A”), verbal fluency (e.g., repeat this sentence after me), and abstract thinking (e.g., tell me how these two items are alike). The maximum score on this test was 30 and scores below 26 indicate potential cognitive impairment for those with at least a high school education. All participants then completed the Shipley Institute of Living Vocabulary test (Shipley & Burlingame, 1941). This was a 40-item test where participants were provided a target word and four optional words, and they must choose which optional word is closest in meaning to the target word. The maximum score on this test was 40. All procedures used in this study were approved by the research ethics board at Brock University.

Results

The analytic strategy utilized in the present study mirrored analyses used by Mahy et al. (2018). Table 1 shows means and standard deviations for accuracy and reaction times on the Raven's matrices (delay task), Lexical decision task (ongoing task), and the PM task by age group and condition.

Cognitive and vocabulary assessments

To assess overall cognitive functioning, participants completed the MoCA (Nasreddine et al., 2005) and the Shipley Institute of Living Vocabulary test (Shipley & Burlingame, 1941). There was no significant difference in MoCA scores across younger ($M = 26.82$, $SD = 2.71$) and older adults ($M = 27.07$, $SD = 2.39$), $t(115) = .536$, $p = .593$. However, older adults performed significantly better ($M = 34.16$, $SD = 3.90$) than younger adults ($M = 27.22$, $SD = 3.49$) on the vocabulary test, $t(115) = 10.15$, $p < .001$, $d = 1.88$. Although younger adults' MoCA scores were not significantly correlated with PM accuracy, $r(60) = .028$, $p = .832$, older adults' MoCA scores were significantly positively correlated with PM accuracy, $r(57) = .371$, $p = .004$.

Delay task performance: Raven's matrices

Performance on the delay tasks indicated that younger adults were more accurate ($M = .60$, $SD = .34$) compared to older adults ($M = .55$, $SD = .33$), $F(1, 113) = 4.48$, $MSE = .016$, $p = .038$, $\eta_p^2 = .038$, and faster to respond ($M = 9,454.71$ ms, $SD = 9,348.24$) compared to older adults ($M = 16,237.93$ ms, $SD = 16,496.19$), $F(1, 110) = 14.20$, $MSE = 111,618,099.5$, $p < .001$, $\eta_p^2 = .114$. In addition, participants in the easy condition were more accurate ($M = .88$, $SD = .11$) and faster to respond ($M = 5,189.81$ ms, $SD = 3,196.82$) compared to the difficult condition ($M = .27$, $SD = .15$; $M = 206,889.66$, $SD = 15,785.00$), $F(1, 113) = 676.27$, $MSE = .016$, $p < .001$, $\eta_p^2 = .857$ and $F(1, 110) = 64.43$, $MSE = 111,618,099.5$, $p < .001$, $\eta_p^2 = .369$. There were no significant age group by delay task difficulty interactions ($ps > .05$). Thus, the difficult task was more challenging than the easy task for both age groups.

Ongoing task performance: lexical decision task

On average, participants had high accuracy on the Lexical Decision task ($M = .85$, $SD = .08$). A 2 (Age Group: younger vs. older adults) x 2 (Delay task difficulty

condition: easy vs. difficult) ANOVA on lexical decision task accuracy revealed a significant main effect of age group, $F(1, 113) = 71.13$, $MSE = .004$, $p < .001$, $\eta_p^2 = .386$, with older adults ($M = .90$, $SD = .05$) outperforming younger adults ($M = .79$, $SD = .08$). There was no significant effect of delay task difficulty condition, $F(1, 113) = .415$, $MSE = .004$, $p = .521$, $\eta_p^2 = .004$, and no significant age group by condition interaction, $F(1, 113) = .005$, $MSE = .004$, $p = .942$, $\eta_p^2 = .000$.

Similarly, a 2 (Age Group: younger vs. older adults) \times 2 (Delay task difficulty: easy vs. difficult) ANOVA on reaction time (for accurate trials) revealed a significant main effect of age group, $F(1, 113) = 71.13$, $MSE = 168,886.891$, $p < .001$, $\eta_p^2 = .386$, with younger adults responding significantly faster ($M = 1,407.85$, $SD = 307.95$), than older adults ($M = 1,809.40$, $SD = 491.45$). There was no significant main effect of delay task difficulty condition, $F(1, 113) = .415$, $MSE = 168,886.891$, $p = .521$, $\eta_p^2 = .004$, and no significant interaction between age group and delay task difficulty condition, $F(1, 113) = .005$, $MSE = 168,886.891$, $p = .942$, $\eta_p^2 = .000$. Thus, these findings suggest that older adults were more accurate, but slower than younger adults on the lexical decision task indicative of a speed-accuracy trade-off.

Prospective memory performance

On average, participants had a 47% accuracy rate ($M = 0.47$, $SD = .39$) on PM trials. Given that PM trials were embedded within an ongoing task (lexical decision task) and that age effects could have been driven by differences in ongoing task performance, we controlled for lexical decision task accuracy (see Marsh, Hancock, & Hicks, 2002). Thus, a 2 (Age Group: younger vs. older adults) \times 2 (Delay task difficulty condition: easy vs. difficult) ANCOVA on PM accuracy with lexical decision task accuracy entered as a covariate was conducted.¹ This analysis revealed a significant main effect of age group, $F(1, 112) = 5.77$, $MSE = .149$, $p = .018$, $\eta_p^2 = .049$, such that younger adults displayed significantly greater PM accuracy ($M = .58$, $SE = .06$) compared to older adults ($M = .36$, $SE = .06$). There was no significant main effect of delay task difficulty condition, $F(1, 112) = 1.98$, $MSE = .149$, $p = .162$, $\eta_p^2 = .017$, and no significant interaction between age group and delay task difficulty condition, $F(1, 112) = .003$, $MSE = .149$, $p = .958$, $\eta_p^2 = .000$. Notably, this significant effect of age group persisted when additionally controlling for level of tiredness and interest in the delay task, $F(1,109) = 7.60$, $MSE = .149$, $p = .007$, $\eta_p^2 = .065$, demonstrating that the differences in younger and older adults' PM performance was not a result of engagement with or state during the tasks.

A 2 (Age Group: younger vs. older adults) \times 2 (Delay task difficulty condition: easy vs. difficult) ANCOVA on reaction times for accurate PM trials with lexical decision task accuracy entered as covariates revealed a significant main effect of age group, $F(1, 72) = 19.80$, $MSE = 185,831.376$, $p < .001$, $\eta_p^2 = .216$, with younger adults responding significantly faster ($M = 1375.37$ ms, $SE = 74.28$) than older adults ($M = 1937.82$ ms, $SE = 86.22$). There was no significant main effect of delay task difficulty condition, $F(1, 72) = .257$, $MSE = 185,831.376$, $p = .614$, $\eta_p^2 = .004$, and no significant age group by delay task difficulty condition interaction, $F(1, 72) = .085$, $MSE = 185,831.376$, $p = .771$, $\eta_p^2 = .001$.

PM performance and thinking about the PM intention

We measured the extent to which participants thought about the PM intention during the delay task at two-time points: (1) during the delay task, and (2) after the delay and PM tasks were completed.

Reporting on the PM intention during the delay task

A 2 (Age Group: younger vs. older adults) x 2 (Delay task difficulty condition: easy vs. difficult) ANOVA on the mean number of times that the PM intention was mentioned during the three thought probes was performed. Results revealed a significant main effect of age group, $F(1, 117) = 5.33$, $MSE = 1.84$, $p = .023$, $\eta_p^2 = .045$, indicating that older adults reported thinking about the PM intention significantly more often ($M = .32$, $SD = .78$) than younger adults ($M = .07$, $SD = .31$). There was no main effect of condition, $F(1, 117) = 2.66$, $MSE = .921$, $p = .106$, and no significant interaction, $F(1, 117) = .165$, $MSE = .057$, $p = .685$. The number of times participants reported thinking about the PM intention was not related to later PM accuracy (*Younger Adults*: $r(60) = .148$, $p = .259$; *Older Adults*: $r(57) = .061$, $p = .652$).

Reporting on the PM intention after the delay task

Upon completing the lexical decision task, participants were asked what they were supposed to do in the task to assess if they recalled the PM instruction. Most participants recalled the PM instruction after the first request (75% of younger adults and 79% of older adults), with a minority of participants recalling the instruction from the subsequent prompts.

Participants then reported if they thought about the PM intention during the delay task. To examine the influence of age group and delay task difficulty on participants' responses, a binary logistic regression was performed with response (0 = no; 1 = yes) as the outcome variable and age group, condition, and the interaction entered on consecutive steps as predictors. Age group was significant on step 1, $\chi^2(1, N = 117) = 4.48$, Nagelkerke $R^2 = .05$, $p = .034$, demonstrating that younger adults were significantly more likely to state that they thought about the PM intention (67%; $n = 40$) compared to older adults (47%; $n = 27$), $B = -.799$, $Wald = 4.39$, $p = .036$, odds ratio = 2.22. Neither delay task difficulty condition, $\chi^2(1, N = 117) = .438$, Nagelkerke $R^2 = .05$, $p = .508$, nor the interaction, $\chi^2(1, N = 117) = .015$, Nagelkerke $R^2 = .05$, $p = .903$, were significant. Within each group, those who reported thinking about the PM intention displayed superior PM accuracy (*Younger Adults*: $r(60) = .561$, $p < .001$; *Older Adults*: $r(57) = .322$, $p = .015$).

Next, participants who reported thinking about the PM intention indicated the number of times they thought about the intention. A 2 (Age Group: younger vs. older adults) x 2 (Delay task difficulty condition: easy vs. difficult) ANOVA was performed on the number of times one thought about the PM intention. There was a significant main effect of age group, $F(1, 62) = 4.14$, $MSE = 4.07$, $p = .046$, $\eta_p^2 = .063$, demonstrating that younger adults reported thinking about the intention more often ($M = 3.90$, $SD = 2.23$) than older adults ($M = 2.84$, $SD = 1.65$). There was no significant main effect of delay task difficulty condition, $F(1, 62) = 2.92$, $MSE = 4.07$, $p = .092$, $\eta_p^2 = .045$, and no significant interaction, $F(1, 62) = .588$, $MSE = 4.07$, $p = .446$, $\eta_p^2 = .009$. Although the main effect of delay task difficulty was non-significant, the pattern of results trended in the same direction where the average number of times one thought about the PM intention was higher in the easy condition (*Younger*

Adults: M = 4.15, SD = 2.64; Older Adults: M = 3.50, SD = 1.45) compared to the difficult condition (*Younger Adults: M = 3.67, SD = 1.80; Older Adults: M = 2.23, SD = 1.64*). The number of times participants reported thinking about the PM intention was positively correlated with PM accuracy (*Younger Adults: r (41) = .467, p = .002; Older Adults: r (25) = .592, p = .002*).

Given the significant relationships between thinking about the PM intention, age group, and PM accuracy, we conducted an analysis to examine if thinking about one's PM intention explains the age group difference in PM accuracy. As there were no significant condition differences across these variables, condition was not included. An ANCOVA was performed on PM accuracy with age group entered as the predictor and the number of times one retrospectively reported thinking about the PM intention and lexical decision task accuracy entered as covariates. The number of times one thought about the intention was the only significant covariate, $F(1, 60) = 18.88$, $MSE = .082$, $p < .001$, $\eta_p^2 = .239$, and when this was controlled for, the effect of age group became non-significant, $F(1, 60) = 2.21$, $MSE = .082$, $p = .143$, $\eta_p^2 = .035$.

Finally, participants indicated if the PM intention was always present in their mind. Although there were no significant differences across age group and condition in terms of the frequency of reporting if the intention was always present ($p > .05$), having the intention always present in one's mind was significantly positively correlated to PM accuracy, $r(117) = .530$, $p < .001$. A Fishers z-test indicated that the magnitude of the correlation between having one's PM intention always present and PM accuracy was significantly stronger in the easy condition, $r(59) = .654$, $p < .001$, compared to the difficult condition, $r(58) = .373$, $p = .004$; $z = 2.06$, $p = .039$.

Given the significant relation between having the PM intention always present and PM accuracy, a final 2 (Age Group: younger vs. older adults) \times 2 (Delay task difficulty condition: easy vs. difficult) ANCOVA was performed on PM accuracy with having the intention always present and lexical decision task accuracy entered as covariates. Having the intention always present emerged as a significant covariate, $F(1, 111) = 48.58$, $MSE = .105$, $p < .001$, $\eta_p^2 = .304$; however, the effect of age group persisted, $F(1, 111) = 9.62$, $MSE = .105$, $p = .002$, $\eta_p^2 = .080$, demonstrating that having the PM intention always present in one's mind did not fully account for the age group differences in PM performance.

Discussion

The present study examined the impact of delay task difficulty on younger and older adults' PM performance. We were specifically interested in how delay task difficulty impacted the extent to which participants thought about their PM intention during the delay interval and thus affected their PM performance.

PM performance

First, we found that younger adults had superior PM performance compared to older adults, regardless of delay task difficulty condition. This age-related decline in PM is consistent with prior literature (Henry et al., 2004; Kliegel et al., 2008; Uttl, 2011). Further, as results have been more inconsistent under event-based (Henry et al., 2004) and focal PM conditions (Henry et al., 2004; Kliegel et al., 2008; McDaniel & Einstein, 2000;

McDaniel & Einstein, 2007; Mullet et al., 2013; Shelton et al., 2011), the present results provide evidence for an age-related decline in PM under these conditions.

Although the difficult delay task was indeed more challenging (lower accuracy and longer reaction times were observed in the difficult vs. easy condition), both younger and older adults showed similar PM performance across these conditions. This suggests that adults' PM performance was not hindered or facilitated by engaging in an easy or difficult task prior to the PM task, aligning with some previous studies with younger adult samples (Cook et al., 2014; Shelton et al., 2013). This finding also contributes to the limited research examining the effect of delay task difficulty on PM among older adults and, in part, aligns with Shelton et al. (2011) who reported that delay difficulty only impacted older adults' PM under certain conditions. Shelton and colleagues found that a more demanding delay task only impacted old-old adults' PM (vs. young-old adults and young adults; Shelton et al., 2013), and that this effect of delay difficulty was only present for old-old adults who completed a non-focal PM task requiring strategic processing (vs. a focal PM task requiring more spontaneous processing). The present results align with these findings as we did not find an effect of difficulty condition on PM with our focal PM cue. Future research should continue to examine this relationship with a larger proportion of old-old adults to extend upon Shelton et al.'s three-way interaction between older adult age group, focal vs. non-focal cues, and PM accuracy. In sum, although we observed an age-related decline in PM under focal cue conditions, this was unaffected by the delay difficulty manipulation.

This lack of condition effect in the current study conflicts with Mahy et al.'s (2018) findings that younger adults had superior PM performance after a difficult delay task (Raven's matrices) compared to an easy delay task (item categorization task). Thus, in Mahy et al.'s study, it may not have been the pacing of the easy and difficult delay conditions that resulted in PM differences. Rather, there may have been something unique about the item categorization task that was particularly damaging to PM performance. The verbal nature of the categorization task may have interfered with the phonological loop and participants' abilities to rehearse their PM intention (e.g., Mahy, Mohun, Müller, & Moses, 2016). Current findings on the effects of the delay task on PM performance suggests that results vary considerably depending on the specific tasks used (Cook et al., 2014; Mahy et al., 2018; Roffler et al., 2014; Shelton et al., 2011, 2013). Although this has contributed to inconsistent findings in the literature, it does support the idea that the content of the delay task can impact PM and researchers should carefully consider which type of delay task they administer.

With regards to the present study, it is possible that the difficult condition was too difficult for participants and that this resulted in less engagement in the task. On average, younger adults in the difficult condition solved only 28% of the matrices correctly, an accuracy rate much lower than was found in Mahy et al.'s difficult condition (64%). As the difficult condition in this study was comprised of the most challenging matrices, it is possible that participants could not decipher the patterns, or attempt a strategy to solve the patterns, thereby reducing their efforts and engagement with the task. In that case, the difficult condition in the present study may be more similar to an easy task as it would not have necessarily recruited the cognitive resources needed to attempt to solve or accurately solve the patterns, helping to explain the null condition effect on PM. A delay consisting of a difficult, but more achievable, task (as used in Mahy et al., 2018) may be what helped participants to solve the patterns at a pace that allowed for cognitive

resources to be allocated to the refreshing of one's PM intention to support later PM performance. Future research examining the impact of the delay on PM and PM intentions may benefit from collecting data from less homogenous groups of younger and older adults as our samples were fairly similar in terms of race and education level.

Thinking about the PM intention

The second goal of our study was to examine what participants thought about during the delay interval and if this differed across age group and delay condition. Older adults were more likely to report thinking about their PM intention compared to younger adults across both the easy and difficult conditions when probed during the delay interval. This partly contrasts previous research showing that older adults tend to engage in less mind wandering (Jackson & Balota, 2012; Krawietz et al., 2012; Reese & Cherry, 2002); however, thinking about one's PM intention can be considered "on-topic mind wandering" in this context as thinking about this information was relevant for the next task. Despite older adults' higher rates of thinking about the PM intention during the delay, doing so did not help to improve their PM performance. Thus, it appears that some older adults forget to carry out their PM intention not because of a lack of preparatory thinking or planning, but because of a simple failure to carry out the PM intention in response to the PM cue. It is possible that older adults become hyper-focused on the ongoing task (lexical decision task) and this pulls their attention away from the PM cue. However, as focal PM cues tend to rely on more spontaneous retrieval processes (McDaniel & Einstein, 2000; McDaniel & Einstein, 2007; Shelton et al., 2011), prior thoughts about the PM intention may be more helpful under non-focal PM conditions where more strategic processing is needed to divide cognitive resources between the ongoing task and PM trials. These results can help to inform strategies that older adults may use to help enhance their PM as it may be particularly important to implement memory strategies that can be used during the target-PM task itself. Future research in this area would benefit from investigating if the delay interval thought probes may inadvertently act as a subtle PM reminder that may trigger participants to think about the PM instructions. Though, we note that our observed PM performance is comparable to previous research, suggesting that these thought probes likely did not have a large effect on PM performance.

When retrospectively asked about thinking about one's PM intention (after all tasks were complete), younger adults were more likely to state that they thought about their PM intention and reported thinking about it a higher number of times during the delay compared to older adults. In addition, for all participants, those who reported thinking about the PM intention and thinking about it more often displayed superior PM performance. Given that this is in contrast with the results when participants were asked to report their thoughts in real-time during the delay task, younger adults' retrospective reporting may have been inflated. It is possible that participants were influenced by their success in the PM task when reporting the extent to which they thought about the PM intention during the delay task. Alternatively, it is possible that younger adults were indeed thinking about their PM intention during the delay task but simply did not disclose this during the

thought probes or were not thinking about it at the moment of the thought probes. Nevertheless, if PM performance does impact one's subsequent reporting of thinking about their intention, this is an important element to consider in future studies. It may be best practice to assess what participants thought about during the delay task prior to the administration of the PM task. In addition to the thought probes utilized in this study, future research can assess various techniques to determine the most effective strategy for reporting thought patterns that occur during the delay task. Given that the current intention monitoring techniques require subjective reports from participants, future consideration could be given to the feasibility of more objective measures.

Notably, when controlling for the number of times one thought about the PM intention, the age effect on PM performance became non-significant. This suggests that it is not necessarily one's age that predicts PM performance, but rather the frequency of thinking about the PM intention, which younger adults reported doing more frequently than older adults, that helps to improve PM performance. However, given that this was retrospective reporting of one's PM intention, perhaps it is one's memory of how much they thought about their PM intention that accounts for the age-related decline in PM. It is possible that those who reported lower frequencies of thinking of the PM intention did so because of a failure to remember the number of times they did think about it, and that these participants also showed poorer PM performance.

Although thinking about the PM intention (when measured by the thought probes and the retrospective report) did not significantly differ across the easy and difficult delay conditions, the positive relation between having the PM intention always present in one's mind and PM accuracy was stronger in the easy condition compared to the difficult condition. This suggests that keeping the PM intention in one's mind may be particularly helpful for PM performance when completing a relatively easy delay task. Perhaps during a difficult task when there are more limited cognitive resources available, keeping one's intention present in the mind contributes to the overload of cognitive resources, thereby not being as beneficial for PM performance compared to those who keep the intention present during an easy task.

Conclusion

Together, the present study found an age-related decline in PM performance, but the age effect was accounted for by younger adults' more frequent retrospective reporting of thinking about the PM intention during the delay. However, it is possible that these retrospective reports were influenced by PM performance. We also found that older adults were more likely to report thinking about their PM intention when asked during the delay task itself, but that this was not related to subsequent PM performance. Having participants complete either an easy or difficult delay task did not impact PM performance. These results contribute to the limited research on how delay tasks affect subsequent PM performance among younger and older adults and help to provide new insight into various methods for capturing what participants thought about during the delay interval.

Note

1. When we ran this analysis controlling for MoCA scores, the results remained the same, such that there was a significant main effect of age group, non-significant main effect of delay condition, and a non-significant age by delay condition interaction.

Acknowledgments

We wish to thank Emily Davis, Amy Holliday, Amanda Krause, Sarah Henderson, Chelsey Masson, and Emily Chemnitz for their assistance with data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

An NSERC Discovery Grant to CEVM that partially funded the research [RGPIN-2015-03774].

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