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Prospective Memory in Young and Older Adults: The Effects of Ongoing-Task Load

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Abstract

Prospective memory involves remembering to perform intended actions in the future. Previous work with the multinomial model of event-based prospective memory indicated that adult age-related differences in prospective-memory performance were due to the prospective (not the retrospective) component of the task (Smith & Bayen, 2006). However, ongoing-task performance was also lower in older adults in that study. In the current study with young and older adults, the difficulty of the ongoing task was manipulated by varying the number of colors per trial to create easier and harder versions of the ongoing task for each age group. The easier version included 2 colors per trial for older adults and 4 colors for young adults. The harder version included 4 colors for older adults and 6 colors for young adults. By adjusting the ongoing-task difficulty, older adults were able to perform the ongoing task as well or better than the young adults. Analyses with the multinomial model revealed that making the ongoing task easier for older adults (or more difficult for young adults) did not eliminate age-related differences in prospective-memory performance and the underlying prospective component.

Keywords

prospective memory; aging; memory; attention; multinomial modeling

The ability to remember to perform actions in the future, such as remembering to take medication or give someone a message is an essential task in our daily lives, referred to as prospective memory (PM). In addition to potential health risks, PM failures can have negative social consequences: imagine the negative effects on a relationship if you never remember to stop at the store when asked to do so by your spouse or partner! While the magnitude of age-related differences can vary with the extent to which PM tasks rely on self-initiated processing (Henry, MacLeod, Phillips, & Crawford, 2004), age-related differences in the laboratory have been found across different levels of processing demand (Kliegel, Jäger, & Phillips, 2008). The current experiment addresses two questions. First, how is PM of young and older adults affected by variations in cognitive demands of ongoing activities? Second, if the ongoing task is adjusted so that the older adults' ongoing-task accuracy is as good as or better than the ongoing-task accuracy of the young adults, will young adults continue to show better PM performance relative to the PM performance of

older adults? The latter question is addressed through the application of a multinomial processing tree (MPT) model of prospective memory (Smith & Bayen, 2004).

The MPT model of event-based PM provides a measure of the prospective component of the PM task (i.e., remembering *that* something is to be done) and also measures the retrospective component (i.e., recognition memory for target events). In this way, the MPT model goes beyond the traditional approach of simply analyzing the proportion of correct PM responses. The limitation of the traditional approach is that when a variable affects the proportion of correct PM responses, it is not possible to say whether the variable affects the prospective component or the retrospective recognition component without concern that these measures are confounded (cf. Jacoby, 1991). In contrast, the MPT model provides separate measures of these components. Of particular interest in the current discussion, Smith and Bayen (2006) applied the MPT model and found that age-related differences in favor of young adults in observable PM performance were entirely due to differences in the *prospective component*. Previous applications of the model indicated that the prospective component relies on resource-demanding processes in a variety of PM tasks (Smith & Bayen, 2004, 2005; Smith, Persyn, & Butler, in press). Therefore, these results concur with a large body of research indicating that older adults' cognitive resources are reduced relative to younger adults' (Light, 1996; Rogers & Fisk, 2001; Salthouse, 1988), thereby affecting PM.

Importantly, Smith and Bayen (2006) also found an age-related difference in ongoing-task performance. Because PM tasks are often performed in the midst of other activities (e.g., remember to interrupt your usual drive home to stop at the store), laboratory PM tasks are embedded in an ongoing task. For instance, while performing an ongoing lexical-decision task, participants may have the PM task of remembering to press the F1 key if they see a target word. In the current study, we used a color-matching task as ongoing activity. Previous studies with young (Smith & Bayen, 2004; Smith, Hunt, McVay, & McConnell, 2007) and older adults (Schnitzspahn, Horn, Bayen, & Kliegel, in press; Smith & Bayen, 2006) used a version of this task in which participants saw four color rectangles, one at a time, followed by a probe item (a word shown in any of five different colors). Participants then decided whether the color of the probe item matched any of the four color rectangles shown on that trial. In the Smith and Bayen (2006) study, younger adults were better at the PM task, but also better at the ongoing task. It is thus possible that age-related differences in the prospective component in that study were driven by the fact that the ongoing task was more difficult for the older adults. That is, a task with the same four colors per trial for both young and older adults may have absorbed relatively more of the older adults' resources that were then not available for the prospective component of the PM task. In the current experiment, we manipulated the difficulty of the ongoing task in order to adjust ongoing-task performance in young and older adults. This allowed us to address the question of whether we would continue to find age-related differences in the prospective component when the two age groups were more similar with respect to ongoing-task performance (see Somberg & Salthouse, 1982, for a similar approach in a dual-task paradigm).

Research involving young adults and divided attention in PM tasks indicates that varying the ongoing-task demands will not always affect PM. For instance, Otani, Landau, Libkuman, St. Louis, and Kazen (1997) found no decrease in PM as a function of adding a secondary divided-attention task. However, other studies did find that divided attention decreased PM performance (e.g., McDaniel, Robinson-Riegler, & Einstein, 1998; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Current models of working memory can account for this disparity (e.g., Baddeley, 2007). To illustrate, consider Baddeley's model, which includes a controlling attentional system (the central executive) that supervises a number of subsidiary "slave" systems (e.g., a phonological loop, involved in speech-based processing, and a visuospatial sketchpad that stores and manipulates visual images). Support for Baddeley's

model comes from findings in the dual-task literature demonstrating that performance in a primary task does not necessarily break down if a secondary load is added. For instance, performing a secondary task that required memorization of number sequences while performing a sentence-reasoning task did not affect reasoning accuracy (Baddeley, 1986). These types of findings are consistent with the proposal that there are subsidiary systems for modality-specific information that operate relatively independently, sometimes requiring little or perhaps no executive control. Deriving predictions from this model, Marsh and Hicks (1998) found that divided-attention tasks that increased the demand for executive control (e.g., random number generation) decreased PM performance (see also Marsh, Hancock, & Hicks, 2002), while tasks that impose a load on the “slave” systems of working memory, but require little in the way of executive control once initiated (e.g., articulatory suppression in the phonological loop) did not affect PM performance.¹ Thus, for young adults, simply manipulating the load associated with the ongoing task in the absence of a manipulation of the demands on the central executive does not necessarily affect PM. The current experiment is the first to investigate whether a similar outcome can be demonstrated for older adults.

Previously, Horn, Bayen, Smith, and Boywitt (2011) found that increasing the number of colors in the ongoing color-matching task did not affect young adults’ observable PM performance. This finding is consistent with work by Marsh and Hicks (1998) and indicates that changing the difficulty of the ongoing task via a manipulation of short-term memory load without changing the executive control demands is insufficient for affecting young adults’ PM performance in this paradigm. Thus, our manipulation extends this to investigate the effects of varying the ongoing task short-term memory load for older adults, and will provide a replication of previous findings with young adults.

Method

Participants

Fifty-four participants were recruited through a department participant pool or newspaper advertisements and received course credit or \$20 as compensation. All participants reported their health as good or excellent and were screened for health problems that could affect memory performance, such as stroke, head injury, or heart attack. The 25 older participants had completed more years of formal education and scored higher on the Gardner-Monge (1977) vocabulary test than did the 29 young adults (Table 1).

Design

In addition to the variable of age group (young vs. older), the design included a within-subject manipulation of ongoing-task difficulty (easy vs. difficult). Each participant completed two blocks of the ongoing task with an embedded PM task. One block included the easy version of the ongoing task and one block included the difficult version of the ongoing task (see Table 2). The easy block included four color rectangles on each trial in the case of young adults and two color rectangles per trial for older adults. The difficult block included six and four color rectangles per trial for young and older adults, respectively. Sixteen young adults and twelve older adults completed the easy task followed by the difficult task; the remaining participants completed the tasks in the opposite order.

¹Note that other models of working memory may also account for negligible load effects on PM if the relevant elements for the PM task and the ongoing task can be simultaneously held in the *focus of attention* (Cowan, 1988) or in the *region of direct access* (Oberauer, 2002) with no (or little) competition for common resources.

Materials and Procedure

The materials and procedures were similar to those used by Horn et al. (2011, Experiment 2A). Two sets of target words (six words in each set) and two sets of filler items (56 words each) were selected from a list of 124 English medium frequency words ($M = 136.10$, $SD = 10.24$) drawn from the Kuera and Francis (1967) database. The two PM target lists were matched on word frequency and word length, respectively.

Prior to starting each block of the ongoing task, participants received instructions for the specific version (easy or difficult) of the ongoing task, followed by four practice trials, and were given an opportunity to ask questions about the ongoing task before receiving instructions for the PM task. Participants were instructed that they would learn six words and they should try to remember to press the *I* key, after pressing either the *Y* or *N* key² for the ongoing task, when these words appeared during the next block of the color-matching task. After the PM instructions in each block, participants completed two practice trials for the PM task using the word “music” as the practice PM target. Participants repeated the instructions to the experimenter to be sure that they understood the instructions. After learning the six target words, which differed between the blocks, participants completed a two-minute filler task prior to starting that block of the color-matching task. For the filler task, which was the same in both blocks, participants performed a reaction-time task in which letters (A to Y) appeared on the screen one at a time and participants pressed the key for the next letter in the alphabet. After completing the filler task, participants began the ongoing task without any reminders of the PM task.

Table 2 presents a scheme of the ongoing-task difficulty manipulation. Variations of the ongoing task were selected so that older adults would perform as well as or better than young adults. Based upon levels of ongoing-task performance seen in previous experiments with young adults comparing 4- and 6-color versions of the color-matching task (Horn et al., 2011) and for older adults with the 4-color version in Smith and Bayen (2006), we selected 2-, 4-, and 6-color versions of the task for the current experiment. Similar manipulations have been used in other studies to affect visual short-term memory (e.g., Klauer & Zhao, 2004). As noted above, previous studies used a version of the color-matching task that included four color rectangles per trial (Smith & Bayen, 2006). This 4-color version served as the easy task for young adults and as the difficult task for older adults (Table 2). The colors white, blue, green, yellow, and red were used in the 4-color version. The colors red, blue, and green were used for the 2-color version of the task, which served as the easy version for the older adults. The colors yellow, blue, red, green, white, magenta, and cyan were used for the 6-color version of the task, which served as the difficult version of the task for young adults. In the 2- and 4-color versions of the task, participants completed 56 nontarget trials plus the six target trials for a total of 62 trials. In order to have the probe color on match trials appear equally often as the first, second, third, etc. color rectangle, the number of nontarget trials was increased to 60 for a total of 66 trials in the 6-color version of the task. In all versions of the task, each trial began with a 250 ms blank screen and the display times for the colors and intervening blank screens were adjusted for each version (Table 2) so that in all versions a total of 3250 ms elapsed between the start of the trial and the appearance of the probe word. Participants responded by pressing the *Y* key if the color of the probe word matched a color shown on that trial and pressed the *N* key if the color of the probe word did not match any of the colors shown on that trial. Following their response,

²The program recorded all responses. If participants pressed the *I* key before pressing the *Y* or *N* key, this was considered a PM response and these are included in the response frequencies in the Appendix and in the proportion of correct responses reported in Table 3. Early PM responses were rare and accounted for less than 2% of all PM responses recorded. Four young adults made the PM response before making the ongoing task response on a combined total of eight trials. One older adult made the PM response before the ongoing response on one trial.

participants were prompted to press the space bar to begin the next trial of the color-matching task.

Each block included PM target words on every tenth trial starting with the tenth trial. This distribution was selected to maximize the distance between target events and to match the procedures used by Smith and Bayen (2006). Half of the target trials and half of the filler trials were match trials (the color in which the word appeared matched one of the color rectangles on that trial) and the other half of the target and filler trials were non-match trials (the color of the word did not match any of the colors shown on that trial). The order of match and non-match trials was randomly determined for each participant. After completing each block of the ongoing task, participants recalled the action (pressing the *I* key) and completed a recognition test for the PM target words. The target recognition test included the six target words and six filler words from the ongoing-task block. Participants who failed to recall the action and also made no PM responses were excluded and replaced. Participants who made no PM responses, but who could recall the action, were included in the reported data set.

After completing the target recognition test for the first block of the PM task, participants completed a vocabulary test. At the end of the experimental session, participants completed a health and demographics questionnaire.

The Multinomial Model

We applied the MPT model of event-based PM (Smith & Bayen, 2004) that we developed for ongoing tasks with two trial types (e.g., match and nonmatch) with PM targets that appear on both ongoing trial types. There are thus four trial types: PM target trials on which the color matches, target trials on which the color does not match, nontarget trials on which the color matches, and nontarget trials on which the color does not match. Each trial type is represented by a tree in the MPT model (Figure 1). The task includes three response options for each trial: match, nonmatch, and the PM response.

As noted earlier, the model includes parameters that measure the retrospective recognition of target events (Parameter *M*), and the prospective component (Parameter *P*). One question of interest in the PM literature is whether the prospective component involves resource demanding processes (e.g., Einstein & McDaniel, 2010; Smith, 2010). For instance, the multiprocess view proposes that the extent to which PM tasks rely on resource demanding processes for the prospective component is determined at least in part by the focal or nonfocal nature of the PM task (Einstein & McDaniel, 2010). The focal/nonfocal nature of the PM task is determined by the relationship between the PM task and the ongoing task. The current PM task is a nonfocal task because the ongoing task (detect color matches) does not require processes that direct attention to the defining characteristics of the PM target events (specific words). If the PM task were to press the *I* key if a specific color appeared during the color-matching task (e.g., Smith, et al., 2007), the PM task would be a focal task. The multiprocess view predicts that focal PM tasks should require fewer resources or perhaps no resources for the prospective component. In contrast to the multiprocess view, the preparatory attentional and memory processes theory (PAM theory; Smith, 2003, 2008, 2010) proposes that resources are always required for the prospective component of event based PM tasks. There is evidence that both nonfocal and, in at least some cases focal PM tasks, can involve resource demanding preparatory attentional processing (e.g., Smith et al., 2007) and age-related differences in favor of young adults are found on both focal and nonfocal tasks (Kliegel et al., 2008). More importantly, the current study involves a nonfocal PM task and both the multiprocess view and the PAM theory would agree that resources are involved in the prospective component of this PM task. Previous evidence indicates that the execution of the prospective component of this PM task requires resources (Smith & Bayen,

2004, 2006; Smith et al., 2007). Thus, we will refer to the prospective component as preparatory attentional processing (Smith, 2003, 2008, 2010). PM also involves recall of the action; however, when using a simple action, action recall is unlikely to explain much of the variability in PM performance (see Smith & Bayen, 2004, for additional discussion). Furthermore, as noted above, participants who could not recall the action and who also failed to make any PM responses were replaced.

The MPT model also includes measures for processes involved in the ongoing-task decision. In the first tree of Figure 1, which represents target trials on which the color matches, with probability C_1 , a participant detects that the color matches. With probability P , the participant engages in preparatory attentional processing and if, with probability M_1 , the participant correctly recognizes the target as a target event, the participant makes the PM response. If the participant engages in preparatory attentional processing but fails to recognize the target ($1 - M$), the participant may still guess that this is a target with probability g and make the PM response. If the participant does not guess that it is a target ($1 - g$), then the participant will respond *nonmatch* because he/she had detected the color match. If the participant detects the color match, but does not engage in preparatory attentional processing ($1 - P$), then the participant will respond *match*. The bottom half of the tree represents the case in which the participant does not detect the color-match, which happens with probability ($1 - C_1$). The parameters P , M_1 , and g , are the same in the bottom half of the tree. However, in cases in which a PM response is not made, the participant must guess about the color-match status of the item. With probability c , the participant will guess that the color matches and make a match response. With probability ($1 - c$) the participant will guess that the color does not match and make a nonmatch response.

The second tree represents target trials on which the color does not match. In this case, participants will detect that the color does not match with probability C_2 and if they do not engage in preparatory attentional processing or if they engage in preparatory attentional processing but fail to recognize the target and also do not guess that it is a target, the participant will make the *nonmatch* response. In the bottom half of the second tree, participants will fail to detect that the color does not match ($1 - C_1$) and when a PM response is not made, they will have to guess about the status of the color match. Parameters P , M_1 , g , and c , function in the same way in this and the first tree.

The third and fourth trees represent nontarget trials and parameters P , g , c , C_1 , and C_2 , function as described for the first two trees. If a participant engages in preparatory attentional processing and correctly recognizes that the item is not a PM target with probability M_2 , he/she will not make the PM response and will make either the match or nonmatch response instead. If the participant engages in preparatory attentional processing, but does not recognize that this is not a target ($1 - M_2$) the participant may still guess that it is a target and make the PM response.

The full model with seven free parameters is not identifiable; thus, Smith and Bayen (2004) imposed the following theoretically motivated constraints. Parameters M_1 and M_2 were set equal and the resulting M parameter measures the ability to discriminate between target and nontarget events. Assuming that participants engage in probability matching, the guessing parameters g and c are set to the proportion of target trials (.10), and to the proportion of match trials (.50), respectively. This model-version has been successfully validated and shown to be identifiable (Horn et al., 2011; Smith & Bayen, 2004, 2005).

Results

Prospective Memory Performance and Post-Task Target Recognition

An alpha level of .05 was used for all tests of statistical significance. The proportion of targets to which participants made a correct response is shown in Table 3. A mixed model analysis of variance (ANOVA) indicated a significant effect of age group in favor of the young adults, $F(1,52) = 7.54$, $p = .008$, $\eta_p^2 = .13$, who were more likely than the older adults to remember to perform the PM task. The main effect of ongoing-task difficulty was not significant and the two variables did not interact, $F_s < 1$.³ The PM results replicate previous findings with young adults (e.g., Horn et al., 2011; Marsh & Hicks, 1998) and replicate the age-related difference in PM performance in Smith and Bayen (2006).

As noted above, participants completed a PM target recognition test following each block of the ongoing task. This provides a post-task explicit measure of target recognition, which supplements, but does not replace, the online retrospective memory measure provided by the MPT model. One problem with drawing conclusions from post-task retrospective measures alone is that recognition of PM targets at the time they appear *during* the ongoing task may differ from recognition *after* the task. For instance, correctly responding to identified PM targets could induce rehearsal of these targets and lead to better subsequent post-task recognition (see Smith & Bayen, 2004, for further discussion). In the analysis of corrected post-task PM target recognition (Table 3), only the main effect of age group reached significance, $F(1,52) = 7.74$, $p = .008$, $\eta_p^2 = .13$. The main effect of ongoing-task difficulty was not significant ($F < 1$), and the variables did not interact, $F = 1.05$, $p = .31$.

Because there was a significant effect of age group on post-test target recognition, we conducted an additional analysis to evaluate the contribution of post-test target recognition to PM performance. We collapsed over ongoing-task difficulty and analyzed the effects of age group on PM performance, while controlling for post-task target recognition performance by including corrected target recognition as a covariate. The age group difference in PM performance remained reliable, $F(1,51) = 4.09$, $p = .048$, $\eta_p^2 = .07$.

Ongoing-Task Performance

As in previous studies (e.g., Horn et al., 2011; Smith & Bayen, 2004, 2006), we examined ongoing-task performance on the five trials preceding each PM target event. The ability to correctly discriminate match and non-match trials (as measured by hit rate for match trials minus false-alarm rate for non-match trials) is shown in Table 3. The main effects of task difficulty, $F(1,52) = 32.54$, $p < .001$, $\eta_p^2 = .39$, and age group, $F(1,52) = 9.93$, $p = .003$, $\eta_p^2 = .16$, were both significant. The two variables did not interact, $F(1,52) = 1.90$, $p = .17$. For both age groups, varying the number of color rectangles on each trial impacted ongoing-task performance.

Prior to analyzing response-time data (shown in Table 3), we excluded trials on which an inaccurate color-matching response was made and trials with response times of less than 200 ms or more than 2.5 standard deviations from an individual's mean response time in each block. The main effect of age group was not significant, $F(1,52) = 2.70$, $p = .11$, and the

³The order of the easy and harder ongoing task blocks was counterbalanced so that approximately half of the participants in each age group completed the easier ongoing task in the first block, while the other half completed the easier ongoing task in the second block. We compared performance in the easier and harder task conditions in the first block only by using a between-subjects comparison of task difficulty and age group. The main effect of age group was significant, $F(1,50) = 10.41$, $p = .002$, $\eta_p^2 = .17$, but the effect of ongoing task difficulty was not significant and the two variables did not interact, $F_s < 1$, $p_s > .73$. In addition, we investigated whether the order in which the tasks were performed (easy followed by hard or hard followed by easy) affected performance on the two blocks. For neither the young or older groups was the effect of task order significant and the order of tasks did not interact with task difficulty, $F_s < 1.79$, $p_s > .19$.

main effect of task difficulty, $F(1,52) = 7.26$, $p = .009$, $\eta_p^2 = .12$, was qualified by an interaction, $F(1,52) = 10.73$, $p = .002$, $\eta_p^2 = .17$. The age group difference was significant in the difficult condition, $F(1,52) = 7.59$, $p = .008$, $\eta_p^2 = .13$, but not in the easy condition, $F < 1$.

Multinomial Modeling

The MPT model was fit to the response frequency data shown in the appendix and the best fitting parameters were estimated via the maximum likelihood method using available modeling programs (Moshagen, 2010; Stahl & Klauer, 2007). The goodness-of-fit between the model predictions and the observed data is indicated by the log-likelihood statistic $G^2(4)$, which is asymptotically χ^2 -distributed (Hu & Batchelder, 1994). The model provided a good fit to the data in each age group for each difficulty condition (Table 4). The power⁴ to detect even small deviations (i.e., effect size $w = 0.10$) from the observed data ranged from .90 to .96. Significance tests of the effects of ongoing-task difficulty on all four model parameters (Figure 2) were conducted for each age group and the effects of age were compared for each level of ongoing-task difficulty. The values of the test statistic for these comparisons, $\Delta G^2(1)$, can be found in Table 4.

We replicated the findings reported by Horn et al. (2011) for young adults: ongoing-task difficulty affected both ongoing-task parameters (i.e., C_1 and C_2) in the expected direction, but neither P nor M was affected by the difficulty of the ongoing task. This pattern was mirrored in the group of older adults, with the only significant effects of ongoing-task difficulty occurring on the ongoing-task parameters. When comparing across age groups, it is clear that within each task difficulty level, older adults performed as well or better on the ongoing task than did the young adults. As in Smith and Bayen (2006), the age groups did not differ in terms of target recognition as measured by M . Importantly, the age-related difference in the prospective component (P parameter) remained significant, even when the older adults were performing the ongoing task at least as well as the young adults. The last line in Table 4 shows the comparison that replicates the age group comparisons reported in Smith and Bayen (2006).

Discussion

We investigated the effects of ongoing-task difficulty on observed PM performance and underlying cognitive processes measured by the MPT model of event-based PM (Smith & Bayen, 2004), in young and older adults. While ongoing-task performance and the associated model parameters were affected by the difficulty manipulation in both age groups, PM performance and the prospective and retrospective components of the task were not affected in either age group. These findings concur with previous such demonstrations with young adults (e.g., Horn et al., 2011; Marsh & Hicks, 1998). To our knowledge, this experiment provides the first demonstration in older adults that ongoing-task difficulty may not affect PM performance when the demands on central executive functioning are not affected by the difficulty manipulation. Importantly, when older adults' ongoing-task accuracy surpassed the young adults' ongoing-task accuracy, the age-related differences in PM performance and in the underlying prospective component of the PM task were not eliminated. Thus, there are age differences in the prospective component of the task (replicating Smith & Bayen, 2006) that cannot be explained by differences in the demands of the ongoing task.

⁴Power analyses were performed with G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007).

A recent study by Bisiacchi, Tarantino, and Ciccola (2008), in which PM performance was examined in young and older adults, also appears to have manipulated working-memory load. In one condition of the Bisiacchi et al. study, participants performed the PM task of responding to a picture of “bread” in the midst of an ongoing picture-naming task. In a second condition (the PM + working-memory load condition) participants had to remember the name of the last picture in each of eight blocks of pictures for recall at the end of the task. The addition of the working-memory load significantly reduced PM performance for older adults; however, the addition of a working-memory load (versus no load at all) in the Bisiacchi et al. study adds a requirement to switch attentional focus and therefore likely increased demands on executive control in that study.⁵

In a related vein, previous modeling results suggest that parameter P (measuring the prospective component of the PM task) may also be affected by the addition of a working-memory load *if* this load taps executive resources. In a study by Smith and Bayen (2005), participants completed an ongoing sentence-verification task with an added working-memory load (Experiment 2) or without this additional load (Experiment 1). When comparing these two groups of participants, the addition of the working-memory load significantly reduced the estimates of the prospective component P . Thus, the measure P of the prospective component is likely sensitive to changes in the executive control demands made by the ongoing task. A recent study demonstrated that the addition of a divided-attention task can reduce PM performance and the estimates of the prospective component for both young and older adults (Smith, 2011).

The current work is also consistent with a study by Marsh et al. (2002) in which the nature of the decision required by the ongoing task was varied. When ongoing-task difficulty was manipulated by increasing the number of decisions required by the ongoing task or by requiring a switch between different decisions, PM performance was reduced relative to conditions in which the ongoing task required only a single decision. However, making two related decisions had a smaller impact on PM performance than did making two unrelated decisions. These findings are in line with research on task-switching. That is, keeping only one task-set (or “production rule”; Anderson, 1983) active, as in the case of two related decisions, likely requires fewer executive demands than switches between different task-sets, as in the case of two unrelated decisions (see Monsell, 2003, for a review). Together, the current experiment and the studies by Marsh et al. (2002), Bisiacchi et al. (2008), Smith and Bayen (2005), and Smith (2011) are consistent with the original work by Marsh and Hicks (1998) showing that the effect of ongoing-task difficulty on PM performance depends upon whether the manipulation affects the demands on executive control processes.

The lack of an effect of the current ongoing-task manipulation on PM performance does not imply that resources are not involved in PM performance, nor does this outcome imply that resource differences do not contribute to age-related differences in PM. The age-related difference remains significant in the comparison of PM performance, as well as the prospective component of the task. Given that automatic processes tend to be preserved in older adults while non-automatic resource demanding processes show age-related differences (Jacoby, 1999), the same pattern likely contributes to the age-related differences found in PM tasks (Henry et al., 2004; Kliegel et al., 2008), including the current task.

Notably, the two age groups did not differ in the retrospective recognition component M that measures the ability to discriminate between target and nontarget events in the current study (see Smith & Bayen, 2006, for the same finding). A main conclusion in the recognition

⁵It is the case that PM performance for young adults did not differ significantly between the PM and PM + working-memory load conditions in the Bisiacchi et al. study, but ceiling effects may have contributed to this outcome.

literature has been that recognition is often insensitive to age-related differences (e.g., Craik, 1994; Kausler, 1994), and it is therefore not surprising that there were no age-related differences in the recognition component in the current study, especially given the relatively small number of target items (6 targets).

The lack of an age-related difference on the retrospective component (this study and Smith & Bayen, 2006) may lead to the assumption that the M parameter reflects automatic recognition processes (e.g., “familiarity”; Jacoby, 1991); this conclusion would be premature given that the working-memory load manipulations used so far may not have been sufficient for affecting the recognition of a small number of PM targets. Consistent with the possibility that the retrospective component is not entirely automatic, Smith and Bayen (2005) found that the retrospective component was sensitive to individual differences in working-memory capacity when an additional working-memory load was imposed (Experiment 2). Future research is needed to further investigate the role of resource availability in participants’ ability to discriminate target and nontarget events. However, the model findings to date suggest that researchers should focus more on the prospective component, rather than the retrospective component, when investigating techniques for improving older adults’ PM performance.

As noted above, the current results are consistent with prior work showing that increasing the demands of the ongoing task will not affect PM performance unless the increased difficulty taps executive control processes (Marsh & Hicks, 1998). Nonetheless, alternative explanations are considered here. For instance, it is possible that participants established a certain pattern of resource allocation between the ongoing and PM tasks in the first block and then carried this over to the second block, which would minimize the effects of task difficulty. Specifically, as suggested by a reviewer, participants may have perceived the PM task as more important⁶ than the ongoing task, which would encourage participants to maintain a consistent level of resource allocation to the PM task, even when the ongoing task was more difficult. If this is the case, then it would be possible to see a reduction in PM performance in the harder ongoing task condition if participants perceived the ongoing task to be the more important task. Future research could address this possibility by manipulating ongoing task importance.

Summary

This experiment provides two new pieces of information. First, the results demonstrate that increasing the ongoing-task demands by increasing the number of items to be maintained in working memory does not necessarily affect PM in either young or older adults. This finding is consistent with previous research with young adults (e.g., Horn et al., 2011; Marsh and Hicks, 1998) and to our knowledge this is the first demonstration of this finding in older adults. Second, even when the ongoing task was adjusted so that older adults outperformed the young adults on the ongoing task, older adults continued to show lower levels of observed PM performance, and the application of the MPT model demonstrated that this age-related difference was due to age-related differences in the prospective component of the task.

⁶Because we used a repeated measures design for the ongoing task manipulation we did not include a question of task importance after each block of the ongoing task. Adding an importance question at the end of the first block might have indirectly increased perceived importance of the PM task prior to initiation of the second block and it is unclear how informative a single question at the end of the second block would have been regarding importance in both blocks.

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Appendix

Response Category Frequencies for Each Trial Type Aggregated Over Participants in Each Condition

Age Group		Response		
Ongoing-Task Difficulty	Trial type	“PM”	“Match”	“Nonmatch”
Young Adults				
Easy	Target, match	57	21	9
	Target, nonmatch	53	1	33
	Nontarget, match	27	673	112
	Nontarget, nonmatch	16	39	757
	More difficult			
	Target, match	56	16	15
	Target, nonmatch	46	9	32
	Nontarget, match	21	599	250
Nontarget, nonmatch	19	128	723	
Older Adults				
Easy	Target, match	32	41	2
	Target, nonmatch	30	1	44
	Nontarget, match	11	645	44
	Nontarget, nonmatch	9	20	671
	More difficult			
	Target, match	29	35	11
	Target, nonmatch	34	4	37
	Nontarget, match	19	572	109
Nontarget, nonmatch	14	74	612	

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Figure 1.

The multinomial processing tree model of event-based prospective memory for three responses. PM = prospective memory; C_1 = probability of detecting a color match; C_2 = probability of detecting that a color does not match; P = prospective component; M_1 = probability of detecting a prospective memory target word; M_2 = probability of detecting that a word is not a prospective memory target; g = probability of guessing that a word is a target; c = probability of guessing that the color matches. Adapted with permission from "A multinomial model of event-based prospective memory" by R. E. Smith and U. J. Bayen, 2004, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30, p. 758. Copyright 2004 by the American Psychological Association.

Figure 2. Parameter estimates for each level of ongoing-task difficulty as a function of age group. Dark gray bars represent parameter estimates for older adults. White bars represent parameter estimates for young adults. Error bars represent 95% confidence intervals.

Table 1
Means, Standard Errors, and Age-Group Comparisons for Participant Characteristics

	<u>Young (n = 29)</u>		<u>Older (n = 25)</u>		η_p^2
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Age in Years	20.16	0.51	68.62	1.38	.96*
Education	13.28	0.19	15.68	0.48	.31*
Vocabulary	11.93	0.67	22.44	1.09	.58*

Note: Young = adults 17 to 29 years, Older = adults 60 to 80 years, Education = years of formal education, Vocabulary = number of correct items out of 30 in the test by Gardner-Monge (1977).

* $F_3(1,52) > 23.70, p_s < .001$.

Table 2
Details of the Easy and Difficult Ongoing Task Blocks for Each Age Group

Ongoing Task Version	Ongoing-Task Details			Ongoing-Task Difficulty		
	Colors/trial	Display Duration	ISI	Young	Older	
2-color	2	750	750	n/a	Easy	
4-color	4	500	250	Easy	Difficult	
6-color	6	300	200	Difficult	n/a	

Note: Colors/trial = number of color rectangles on each color-matching trial. Display Duration = time (in ms) that each color rectangle is shown. ISI = interstimulus interval (in ms) following each color rectangle display. n/a = the age group did not perform this version of the task.

Table 3
Proportion of Correct Prospective Memory Responses, Post-Task Recognition Memory, and Ongoing-Task Performance

Age group and condition	Prospective Memory				Ongoing Task			
	Performance		Post-task Target recognition		Discrimination		Response time (in ms)	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Young								
Easy Ongoing Task (4 colors)	.63	.06	.80	.04	.81	.05	1966	121
Difficult Ongoing Task (6 colors)	.59	.05	.74	.04	.55	.04	1923	100
Older								
Easy Ongoing Task (2 colors)	.41	.05	.62	.04	.89	.02	1976	98
Difficult Ongoing Task (4 colors)	.42	.07	.64	.06	.73	.04	2413	152

Note. Target recognition memory is measured as hit rate - false alarm rate on the post-task target recognition test given at the end of each block of the ongoing task. Ongoing task discrimination of match vs. nonmatch items is measured as hit rate - false alarm rate.

Table 4
Goodness-of-Fit Statistics and Parameter Comparisons Between Conditions and Age-Groups

	Comparison	G ² (4) overall model fit	$\Delta G^2(1)$ for Model Parameters			
			P	M	C ₁	C ₂
Young:	Easy (4 colors) vs. Difficult (6 colors)	8.27 8.49	1.18	0.08	57.32 ^c	54.76 ^c
	Easy (2 colors) vs. Difficult (4 colors)	0.61 3.28	1.52	2.46	38.99 ^c	38.07 ^c
Easy:	Young (4 colors) vs. Older (2 colors)		20.63 ^c	0.44	30.51 ^c	4.11 ^a
Difficult:	Young (6 colors) vs. Older (4 colors)		4.68 ^a	1.90	41.44 ^c	7.57 ^b
	Young easy (4 colors) vs. Older difficult (4 colors)		9.84 ^b	1.31	0.80	19.48 ^c

Note: Values of $G^2(4)$ less than 9.49 indicate a good fit of the model to the data in the respective condition. Values of $\Delta G^2(1)$ greater than 3.84 indicate a significant difference in the parameter estimates for the two groups or conditions.

^a $p < .05$
^b $p < .01$
^c $p < .001$.