Effect of Age on Event-Based and Time-Based Prospective Memory

Denise C. Park
University of Michigan

Roger W. Morrell
University of Michigan

Christopher Hertzog and Daniel P. Kidder
Georgia Institute of Technology

Christopher B. Mayhorn
University of Georgia

The magnitude of age differences on event- and time-based prospective memory tasks was investigated in 2 experiments. Participants performed a working memory task and were also required to perform either an event- or time-based prospective action. Control participants performed either the working memory task only or the prospective memory task only. Results yielded age differences on both prospective tasks. The age effect was particularly marked on the time-based task. Performance of the event-based prospective task, however, had a higher cost to performance on the concurrent working memory task than the time-based task did, suggesting that event-based responding has a substantial attentional requirement. The older adults also made a significant number of time-monitoring errors when time monitoring was their sole task. This suggests that some time-based prospective memory deficits in older adults are due to a fundamental deficit in time monitoring rather than to prospective memory.

Recently there has been a great deal of interest in the study of prospective memory in younger and older adults (Brandimonte, Einstein, & McDaniel, 1996). Prospective memory refers to the memory required to carry out planned actions at the appropriate time, such as meeting a friend for lunch or taking a medication. Prospective memory involves retention of an intention to act that has been stored in long-term memory. An important element of prospective remembering is that one is typically engaged in a different kind of action or ongoing cognitive processing at the point in which prospective remembering is required (Park & Kidder, 1996; Park & Mayhorn, 1996).

Prospective memory is important in maintaining function in everyday life, so it is of considerable interest as to whether this type of memory does decline in late adulthood. Although there is substantial evidence that both working memory and long-term memory decline with age (Craik & Jennings, 1992; Park et al., 1996), somewhat less is known about the relationship between aging and prospective memory. Naturalistic research on prospective memory that requires old and young adults to make phone calls or mail postcards at appointed times has yielded mixed evidence, with some studies reporting equivalent performance as a function of age (Poon & Schaffer, 1982), and others reporting age-related decline (Dobbs & Rule, 1987; Maylor, 1990).

Einstein and McDaniel (1990) proposed an important distinction between event-based and time-based prospective memory. They suggested that event-based memory is triggered by some type of event or cue (e.g., a painful joint reminds one to take arthritis medication) and requires less self-initiated processing or mental effort than time-based prospective memory. Time-based prospective memory is more effortful because it requires a participant-initiated response at a specific time in the absence of cues. Einstein and McDaniel developed a laboratory methodology for the study of event-based prospective memory. They presented participants with a short-term verbal memory task and told them, at the same time, to press a key when a certain word was recorded as a measure of prospective memory. They found no evidence for age differences on the prospective task, although significant differences were observed on the short-term memory task, as existing literature predicts.

In contrast to the findings on the event-based task just described, Einstein, McDaniel, Richardson, and Guynn (1995) and Einstein and McDaniel (1996) reported evidence for age-related differences on a time-based task in which participants had to make a keypress after intervals of 10 and 20 min had elapsed while they were performing another task. Einstein et al. also reported that a direct comparison of event-based to time-based prospective memory resulted in an Age × Memory Type interaction because of age differences on the time-based but not on the event-based task.

Despite the initial findings of age invariance for event-based prospective memory, there is evidence that age differences occur on event-based responding when retrospective memory load is high. Einstein, Holland, McDaniel, and Guynn (1992) indicated

References:

that when the participants were required to respond to multiple words as prospective cues (e.g., press the key whenever they saw any one of four different words), age differences were observed. They argued that this was due to an increase in the retrospective or long-term memory requirements of the prospective task. That is, older adults were less likely to remember the full set of cue words so that failure to respond was a result of forgetting the target to which they were to respond rather than of forgetting to respond when cued. On the basis of these findings, Einstein et al. (1992) suggested that when age differences in event-based prospective memory occur, they are due to difficulties with the retrospective components of prospective tasks. Congruent with this interpretation, Kidder, Park, Hertzog, and Morrell (in press) reported that prospective memory was more disadvantaged for older compared with younger participants when the number of prospective targets was increased. However, Kidder et al. also reported that increasing the demands of a concurrent working memory load affected performance on the prospective task and that the effect was somewhat larger for older compared with younger participants. Thus, it appears that retrospective load may not be the only cause of age-related differences in prospective memory.

In the present studies we further explored the relationship of aging to time-based and event-based memory. Our procedures were similar to the tasks developed by Einstein, McDaniel, and colleagues, but we also introduced a number of changes designed to elucidate mechanisms underlying age differences in prospective performance. Specifically, we included new control conditions not used in previous research that were derived from methodologies used in dual-task procedures. The other major change was a decrease in the relationship between the target task and the prospective task compared with past research. The paradigm was the same one that was used by Kidder et al. (in press).

An important aspect of the present studies was based on conceptualizing prospective memory paradigms as a dual-task procedure in which the working memory task and the prospective task were performed simultaneously. Such a conceptualization makes salient the importance of including control conditions in which participants perform either the primary working memory task only or the prospective task only. Previous researchers have examined performance for the working memory task alone but not for the prospective task alone. We have included both types of control conditions in the present studies. Perhaps the age differences observed in time-based prospective memory are due to fundamental, age-related deficiencies in the ability to monitor time rather than to difficulties in switching between the primary task and prospective task. As Maylor (1996) has suggested, there is less linkage in the present studies between the prospective task and the primary task that participants perform with most previous research. In Einstein and McDaniel’s (1990) and Einstein et al.’s (1995) tasks, the event-based cue had to be processed by the participant in order to perform the primary task. For example, Einstein and McDaniel’s participants studied a series of words as a primary task and also made a prospective response if a word belonged to a particular category. Thus, the semantic properties of the word being studied cued the prospective decision (e.g., press a key if the word is an animal). Maylor (1996) has proposed that compatibility of processing for both the prospective and the working memory task may be an important factor in determining whether age differences occur on event-based tasks. She suggested that whenever different processes are required for the prospective and working memory task, age differences occur. Maylor reported age differences on a prospective event-based task when semantic processing was required on the primary task and structural processing was required on the prospective task. Mäntylä (1993) reported a similar finding for a prospective and primary task with different processing requirements. On the basis of this finding, in our event-based task, the working memory and prospective memory tasks were not tightly linked. Research participants performed a verbally based working memory task as the primary task and responded to an unrelated nonverbal cue for the prospective task. Rather than having the prospective event embedded within and strongly linked to the target words in the primary task, participants could achieve good performance on the working memory task without attending to the prospective cue. In the present study, the words in the verbal working memory task were presented against a continuously changing patterned background. The prospective task required participants to respond when a certain background pattern appeared, a cue that is wholly irrelevant to performance on the working memory task. Under these conditions, we expected that the prospective task would require more self-initiated processing despite its event-based nature. We expected that, in contrast to the findings of Einstein and McDaniel (1990) and consistent with the findings of Maylor (1993) and Mäntylä, reliable age differences in performance on the prospective task would occur.

In the present study we also increased the number of prospective events to which participants respond. In Einstein and McDaniel (1990) and Einstein et al. (1992), participants responded to only three prospective events; in the time-based task reported by Einstein and McDaniel (1996), only two prospective responses were recorded. Brandimonte and Passolunghi (1995) reported greater ranges of prospective memory performance when they required college students to make eight responses in the Einstein and McDaniel paradigm. Maylor (1996) has suggested that a limited response scale in prospective memory tasks may lead to unreliable measurement, but she reported good reliability with eight responses on an event-based task. In our study, we presented participants with either 6 or 12 prospective events for each task within a 12-min time frame. We expected age differences to be more likely to emerge on the 12-response task for both event-based and time-based responding, as it would appear to be a more demanding task. However, it is also possible that a greater frequency of responses would enhance the salience and maintain activation of the prospective task so that performance could be better in the 12-event task.

In our time-based prospective task, we examined clock-checking behavior in addition to measuring response latency to the prospective interval. Einstein et al. (1995) found that older adults checked a clock less often to determine the time when a
prospective response should be made. Einstein et al. concluded that the time-based task required more self-initiated processing than the event-based task and that this was the basis for the age difference observed in time-based responding. Thus, Einstein et al. would predict that performance would be poorer on the primary working memory task for time-based compared with the event-based task for both older and younger adults, as the time-based responding would utilize more cognitive resources—a hypothesis we investigated in the present study.

We also included individual differences measures of working memory, processing speed, and verbal ability. This permitted us to estimate the relationship of standard indexes of processing resource (speed and working memory) to age and prospective memory performance, as limitations in resource have frequently been cited as the mechanism underlying age differences that have been observed.

In summary, in the present two experiments we investigated age differences in time-based and event-based prospective memory, including appropriate control conditions that have not been included in past studies. In Experiment 1 we focused on event-based memory as a function of age and event density (6 vs. 12 prospective events over 12 min). In Experiment 2 we examined the same manipulations, except that the prospective events were time-based. We hypothesized that age differences would occur in both event-based and time-based tasks, with a greater likelihood of them emerging in the 12-event prospective tasks. Second, we hypothesized that when performance on the primary working memory task was compared in the time-based and event-based conditions, the cost of performing the prospective task to the working memory task would be greater in the time-based conditions because of the greater self-initiated processing required. Third, we expected that older adults may be deficient in time monitoring when a prospective-only control condition is included, indicating that age effects on time-based responding are not due entirely to the dual nature of a prospective memory task but to a fundamental deficiency in time monitoring. Finally, we expected that the individual differences measures of cognitive resources (perceptual speed and working memory) would better predict time-based responding compared with event-based responding if the Einstein and McDaniel (1990) hypothesis that the time-based task is greater in processing requirements is correct.

**Experiment 1**

The purpose of Experiment 1 was to determine the effects of varying the density of event-based prospective responses for young and old adults by using a laboratory task in which the prospective events were unrelated to performance of the primary task. Additionally, control groups were included to assess performance on either the primary task only or the prospective task only.

**Method**

**Participants**

A total of 96 participants were tested in this experiment: 48 young adults and 48 old adults. The younger adults (8 male and 40 female) were undergraduates at the University of Georgia, with a mean age of 19.21 years ($SD = 0.94$). They participated to fulfill a research requirement for introductory psychology. The older adults (14 male and 34 female) were community-dwelling older adults in Athens, Georgia recruited from an existing participant pool and through newspaper ads; they received $20 for participating. The older adults ranged in age from 57 to 84 years, with a mean age of 69.77 years ($SD = 5.61$). Their mean years of education, reported on a checkoff scale, was 4.40, with responses on the scale ranging from 4 (some college) to 5 (college degree). The two age groups differed on self-reported health (3.75 for younger and 3.10 for older adults on a 5-point scale), $t(94) = 3.53$, $p < .01$, and they approached differing on ratings of health relative to other peers (3.69 for younger and 3.29 for older adults on a 5-point scale), $t(94) = 1.98$, $p = .051$. Younger adults were also taking fewer medications (0.46 for younger and 2.56 for older adults), $t(94) = 7.07$, $p < .001$. Older adults evidenced better performance on the Shipley Institute of Living Vocabulary Test (Shipley, 1986; 30.13 for younger and 34.17 for older adults), $t(94) = 4.16$, $p < .001$.

**Design**

There were 96 participants in the study assigned to six between-groups conditions of 16 participants; each group was created by crossing two ages with three prospective conditions: control (no concurrent prospective task), a 6-event concurrent prospective task, or a 12-event concurrent prospective task. In addition, participants received two phases of trials on the working memory task, which constituted a within-subject variable (Phase 1 and Phase 2). During Phase 1, all participants performed only the working memory task; whereas in Phase 2, the working memory task was performed along with the prospective task for the two groups of participants assigned to prospective memory conditions. Control participants performed only the working memory task in both Phase 1 and Phase 2.

We should also note that there was an additional group of 24 elderly control participants that performed only the event-based prospective task: 12 were assigned to the 6-event condition, and 12 to the 12-event condition. The data for these conditions are analyzed and reported separately. The participant characteristics were comparable to the other older participants already described.

**Experimental Tasks**

There were two experimental tasks developed for this study: a working memory task and an event-based prospective task. Additionally, participants received an individual differences battery.

The working memory task. The working memory task was designed to have relatively high resource requirements so that a simulation could occur of how a person might remember to perform a prospective action when they were highly engrossed in another task. There were two 12-min phases. For both phases, participants were presented with a series of high-frequency words (occurring 50 times or more per million), four to seven characters in length, selected from Thorndike and Lorge (1944). The words were presented in blue type (72-point Helvetica) on a color computer monitor every 3 s in each 12-min phase. Each word was presented against one of six black and white background patterns (shown in Figure 1). Every time the word changed, the background pattern changed. These abstract patterns were conceptually unrelated to any aspect of the working memory task. In both phases, participants were instructed to maintain the words in memory at all times.

The prospective memory task. The prospective memory task was designed to require a dual-task performance of the prospective task. The memory task was performed concurrently to the prospective task.
conditions were also told to press the designated key whenever the target formed the 12-min working memory task as their sole task during Phase 1. Participants performed only the Phase 2 working memory task. Participants were instructed to respond to only one pattern rather than to multiple patterns to keep the retrospective component of the prospective task low. In the 6-event condition, the target pattern appeared once, randomly within each 2-min interval across the 12-min block of time the working memory task occurred. In the 12-event condition, the pattern appeared once randomly, within every 1 min across the 12 min.

**Individual Differences Battery**

The individual differences battery was designed to measure vocabulary ability, to assess basic participant information about health and education, but also to measure working memory and perceptual speed, as these are hypothesized to be mechanisms underlying decline with age in retrospective memory (Salthouse, 1993). To measure vocabulary, participants received the Shipley Institute of Living Scale (Shipley, 1986). Speed was measured by the Digit Symbol subtest from the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981), and working memory was measured by the Reading Span Test developed by Salthouse and Babcock (1990). Measures of health, education, and other demographic variables were taken from Older Americans Resources and Services (OARS) Instrument (Duke University, 1975) by using questionnaires developed from previous research (e.g., Park & Shaw, 1992).

**Procedure**

Participants were individually tested in a session that lasted between 1.0 and 1.5 hr. Participants received instructions and a brief initial training session in the working memory task, and then all participants performed the 12-min working memory task as their sole task during Phase 1. Participants assigned to the 6- and 12-event prospective memory conditions were also told to press the designated key whenever the target pattern appeared. As in Einstein and McDaniel (1990), participants were instructed that the working memory task was their primary task and that they should try not to make any errors on it. The working memory task was primary because in everyday life, prospective responding typically occurs in the context of some ongoing primary task. During Phase 2, control participants were instructed that they were to perform the same memory task again, but with new words. After completion of the memory task, participants were given the individual differences battery. The tasks were administered in the order listed above.

Besides the factorial experiment just described, an additional 24 older participants were assigned to the prospective control condition and performed only the event-based task of responding to the patterns. They were presented with the prospective task just described, with both receiving 6 events and half receiving 12 events. The stimuli were the same patterns as described above except that the words were no longer superimposed upon them. They were instructed to press a key when they saw the target pattern.

**Results**

There were three types of analyses conducted. First was an analysis of proportion correct on the working memory task. Second was an analysis of proportion of correct responses on the prospective memory task for those participants who received it in Phase 2. Finally, the individual differences measures were correlated with the working memory task and with the prospective memory task. Each set of analyses is described below. All effects reported were significant at the .05 level unless otherwise noted.

**The Working Memory Task**

The proportion of recall trials in which participants correctly recalled all three words (in any order) was calculated for each participant in both Phase 1 and Phase 2. The means and standard deviations appear in Table 1. These data were then subjected to a mixed analysis of variance (ANOVA) with age and prospective event density (control vs. 6 event vs. 12 event) as between-

**Table 1**

<table>
<thead>
<tr>
<th>Working memory task</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>.65</td>
<td>.83</td>
</tr>
<tr>
<td>6 event</td>
<td>.63</td>
<td>.80</td>
</tr>
<tr>
<td>12 event</td>
<td>.66</td>
<td>.89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 1: Event-based task</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>SD</td>
<td>P</td>
</tr>
<tr>
<td>Control</td>
<td>.25</td>
<td>.25</td>
</tr>
<tr>
<td>6 event</td>
<td>.22</td>
<td>.22</td>
</tr>
<tr>
<td>12 event</td>
<td>.25</td>
<td>.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 2: Time-based task</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>.25</td>
<td>.25</td>
</tr>
<tr>
<td>6 interval</td>
<td>.22</td>
<td>.22</td>
</tr>
<tr>
<td>12 interval</td>
<td>.21</td>
<td>.21</td>
</tr>
</tbody>
</table>

Note. Data for the control conditions are the same for Experiments 1 and 2. P = proportion.
The analysis yielded a main effect of age, \( F(1, 90) = 24.28, p = .001, \text{MSE} = .074 \), reflecting superior performance of younger adults on the working memory task compared with older adults (marginal means of .72 and .52, respectively). There was also a main effect of phase, \( F(1, 90) = 51.17, p = .0001, \text{MSE} = .011 \), that was due to improvements in performance from Phase 1 to Phase 2 (marginal means of .56 and .67, respectively). These main effects were qualified by a significant Age \( \times \) Phase interaction, \( F(1, 90) = 4.11, p = .046, \text{MSE} = .011 \). Younger adults improved, on average, from .65 to .79 from Phase 1 to Phase 2, whereas older adults improved less, from .48 to .56. No other interactions were significant. Note, in particular, that the number of prospective targets (6 vs. 12 events) had little impact on the working memory task performance for either age group. Moreover, the costs of imposing the prospective task at Phase 2, relative to the control condition, appeared to be low. On average, older adults in the two prospective conditions recalled about 9% fewer sets of words than controls—a nonsignificant difference.

**The Prospective Memory Task**

The number of prospective trials to which a participant responded with a keypress in Phase 2 was recorded for the participants in the 6-event and 12-event conditions. The means and standard deviations appear in Table 2. These data were subjected to a 2 \( \times \) 2 between-groups ANOVA with age and event density as independent variables. There was a main effect of age, \( F(1, 63) = 8.19, p = .0058, \text{MSE} = .039 \), with younger adults responding more accurately (\( M = .93 \)) than older adults (\( M = .79 \)). As can be seen from the sample means, older adults appeared to perform more poorly in the 6-event condition, relative to the 12-event condition, but the interaction of age and event density was not reliable (\( p > .05 \)), and the specific comparison of the two means was also not significant (\( p > .05 \)).

The data from the elderly control participants who performed only the event-based task indicated that all participants responded correctly to every pattern. No errors were made by any participant.

**Individual Differences Measures**

Correlations were computed separately for young and old adults among measured performance on the working memory task, the prospective task, and the individual differences measures: Shipley Vocabulary (a measure of crystallized intelligence), Digit Symbol (a measure of speed or fluid intelligence), and Reading Span (a measure of working memory). We pooled the data for the 6- and 12-event density conditions within each age group to increase sample size for the correlations. Correlations of the individual differences measures with the two phases of the primary working memory task did not differ greatly, and, hence, these two phases were pooled to increase reliability. Performance on the primary working memory task for older adults correlated significantly with Shipley Vocabulary (\( r = .45 \)), Digit Symbol (\( r = .57 \)), and Reading Span (\( r = .40 \)). The corresponding (nonsignificant) correlations for younger adults were .13, .08, and .21, respectively. None of the correlations with prospective memory performance approached significance for younger adults, but some were significant for the old adults. For younger adults, prospective memory correlated .07, .27, and .08 with Vocabulary, Digit Symbol, and Reading Span, respectively. Older adults' prospective memory performance correlated .13, .03, and .34 with the same variables, the only significant correlation being with Reading Span (\( p < .05 \)). Older adults with higher reading span made more prospective errors. The Phase 2 primary working memory task did not correlate with concurrent prospective memory for either group (\( r = .11 \) and .17 for younger and older adults, respectively).

**Table 2**

_Proportion Correct and Standard Deviation for Prospective Memory Task by Age and Condition in Experiment 1_

<table>
<thead>
<tr>
<th>Prospective memory task</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>SD</td>
</tr>
<tr>
<td>6 event</td>
<td>.94</td>
<td>.10</td>
</tr>
<tr>
<td>12 event</td>
<td>.92</td>
<td>.09</td>
</tr>
</tbody>
</table>

Note. P = proportion.

**Discussion**

The present pattern of findings suggested that age differences can occur in prospective memory performance, even when the retrospective memory load associated with the prospective task is low, as participants had only one target pattern to remember in this study. This is consistent with recent work reported by Kidder et al. (in press), Mäntylä (1993, 1996), and Maylor (1996). There were a number of features of the present task that may have led to age differences in prospective memory. First, the working memory task in the present study was very demanding of cognitive resources, as even young adults in the control condition were well below ceiling in the second phase of task performance. Additionally, the prospective task and primary task were not tightly linked, as one was verbal and the other nonverbal. Moreover, the primary task was poorly integrated with the primary task, in the sense that participants need not process the prospective cue to perform the working memory task. Finally, a more sensitive measure of prospective memory was used than has been the case in research in which age differences have not been found.

It is important to note that the present findings did not provide any evidence that performance on an event-based prospective task had significant adverse impact on the working memory task performance of older adults. The Age \( \times \) Phase interaction, which occurred on the working memory task, appears to reflect age differences in learning how to perform the working memory task rather than costs from the addition of the prospective task in Phase 2. Control participants and experimental participants all showed roughly the same degree of improvement across phase.

Older control participants evidenced errorless performance when they performed only the event-based task. Hence, the poorer prospective performance on the part of older participants cannot be attributed to a fundamental deficit in their ability to
detect or remember the target event (e.g., impaired target pattern recognition). The deficits observed on the prospective task appear to occur as a result of the additional requirement that participants perform the working memory task while also performing the event-based prospective task.

It should also be noted that older adults did perform more poorly on the working memory task than younger adults, as well as on the Reading Span task ($M = 2.35$ for older and $M = 3.54$ for younger adults). $t(119) = 3.87, p < .001$. Thus, older adults had less working memory resources available to perform the prospective memory task. Maylor (1996) has argued that there is no relationship between the working memory deficit and prospective performance, other factors besides limited resource are responsible for the prospective deficit. The individual differences data in the present study supported this hypothesis, as the only relationship we found between resource measures and prospective memory was in the opposite direction expected. Nevertheless, because Einstein and McDaniel (1990) presented older adults with a less resource-demanding primary task than the younger adults, it is still possible that we might have observed age invariance for prospective memory if we had used a simpler primary working memory task. The results of Kidder et al. (in press) confirm this hypothesis. Kidder et al., in fact, found no age differences on event-based responding when a two-item working memory load was the recall requirement for the primary task, but they did find age differences on prospective memory in a condition that used the three-item load also used in the present study. It is also important to note that attempting to equate working memory load by adjusting task difficulties for each age group (Einstein & McDaniel, 1990) likely does not create equivalent working memory loads for the individuals in the two age groups. A more effective technique would be to assign each participant a load on the basis of a measure of each individual’s working memory capacity while also providing explicit instructions about relative emphasis on both tasks.

The finding that there were no significant differences in prospective performance between the 6-event and 12-event task suggests that six prospective trials are adequate to detect age differences and that event density beyond this point was not a major influence on performance in this task. Event density clearly had no impact on younger adults’ performance, whereas the sample means for older adults differed by about 0.6 standard deviation units. These sample differences indicated that, if anything, the more frequent cues in the 12-event condition facilitated older adults’ performance. It would be useful to determine if event density becomes more important as retrospective memory load associated with the prospective task increases or as working memory demands on the primary task increase.

In summary, the most important finding from this experiment is that age differences occur on an event-based task with low retrospective requirements. As measured by our task, older adults appear to be poorer than younger adults at event-based prospective memory. The data from the control condition suggested that the deficit, evidenced by the older participants, was due to trying to remember to perform the prospective task while at the same time performing the working memory task. They performed perfectly on the event-based task when it was not placed in the context of ongoing cognitive activity.

Experiment 2

Experiment 2 was nearly identical to Experiment 1, except that a time-based task was used. We presented young and old adults with the primary working memory task described in Experiment 1 as well as a prospective time-based memory task that contained 6 intervals (1 interval every 2 min) or 12 intervals (1 interval every 1 min). We hypothesized that age differences would appear on both the 6-interval and 12-interval tasks. As in Experiment 1, to determine whether any fundamental age differences existed in the ability to monitor time independent of the primary task, we also included a control condition, in which the participants’ sole task was to perform the prospective time-monitoring task in the absence of the working memory task. To keep the retrospective demands of the prospective task low and roughly equivalent to Experiment 1, we asked participants to respond on a fixed rather than on a variable interval scale (e.g., respond every 1-min or 2-min interval). Thus, respondents only had to remember one piece of information (the fixed time interval for response), just as participants had to remember to respond to only one pattern in Experiment 1.

Method

Participants

A total of 112 participants were tested in this study: 56 young and 56 old. The young adults (17 male and 39 female) were college students in the introductory psychology research pool at the University of Georgia and had a mean age of 19.59 years ($SD = 2.07$). One older participant was deleted from the 12-interval, working memory load condition because of his inability to understand the instructions. The 55 remaining community-dwelling older adults had a mean age of 69.8 years ($SD = 5.84$). The 27 male and 28 female older adults were compensated $20 for their participation. The mean years of education, reported on a 5-point scale, was 3.71 ($SD = 0.56$) for the undergraduates and 4.60 ($SD = 1.27$) for the older adults. Self-reported health was 4.07 ($SD = 0.81$) for the younger adults and 3.27 ($SD = 0.83$) for the older adults, a significant difference, $t(109) = 5.15, p < .001$. Rated health relative to peers did not differ between the two age groups with means of 3.93 and 3.65 for young and old, respectively. Older adults were taking more medications than younger adults, with means of 1.85 ($SD = 1.57$) and 0.60 ($SD = 0.87$) for old and young, respectively, $t(108) = 5.18, p < .001$. The Shipley Vocabulary score of the older adults was higher than that for the younger adults, with means of 34.82 ($SD = 4.53$) and 30.41 ($SD = 2.90$), respectively, $t(108) = 6.11, p < .001$. Younger adults had higher Reading Span scores than older adults, with means of 3.30 ($SD = 1.77$) and 2.01 ($SD = 1.02$), respectively, $t(108) = 4.76, p < .001$.

Design

There were 64 participants who concurrently performed the working memory and prospective memory tasks. They were assigned to four groups of 16 participants, each group was created by crossing age with response density (6 or 12 responses). An additional 48 control participants—half young and half old—performed only the prospective task. These participants were only given the time-monitoring task and were required to make 6- or 12 time-based responses at regular time intervals without any other task requirement. This allowed us to determine if there were any basic differences in the ability to respond prospectively at regular time intervals in the absence of a primary task. There were 12 participants in each of the four control conditions that resulted from the
factorial crossing of age with interval density (6 vs. 12 intervals). A second set of control conditions was required consisting of participants who performed only the working memory tasks. We already had data from 32 participants in Experiment 1 who had performed only the working memory task and not the prospective task. Because this working memory task was identical to the one used in Experiment 2, these same participants were used as the control participants in statistical analyses of the Experiment 2 working memory data.

Experimental Tasks

The working memory task was the primary task in which the time-based task was embedded. The working memory task was identical to the one described in Experiment 1, including a 12-min Phase 1 task in which there was no prospective task, followed by Phase 2 in which the prospective task was added for all but the control participants.

For the prospective memory task, participants were asked to pull a lever every 1 min or every 2 min across the 12-min time frame that the working memory task occurred. Participants also had access to a specially designed clock to assist them in checking the time. The clock was placed to the side of the computer monitor and was elevated so that it was even with the center of the monitor. There was a small, handheld device attached to the clock that had a red button and a black lever. The clock displayed the time only when the red button was pushed. Thus, participants were instructed to press the red button whenever they wanted to determine how much time had elapsed from the onset of the experimental task. Participants were also instructed that the black lever was to be pulled when the person thought it was time to make a response. Latencies for both types of responses were recorded separately. Considerable pretesting of this device occurred to be certain that the two tasks were sufficiently discriminable and that confusion between clock checking and prospective responding was not a factor in performance. The devices were modified several times until the situation described here was developed.

The same individual differences battery that was described in Experiment 1 was also administered to all participants, including control participants.

Procedure

Participants were individually tested, as in Experiment 1. The 64 participants performing both the working memory task and the prospective task were instructed that the working memory task was the primary task.

Results

The data analysis consisted of two major components: an analysis of working memory performance and an analysis of prospective performance. The prospective memory analysis includes analyses of response accuracy, clock-checking behavior, as well as correlations of the individual differences variables to these measures. Because the primary task was identical in Experiments 1 and 2, and the density of prospective events was the same, it was also possible to conduct some comparisons of the data from Experiments 1 and 2 by examining how making event-based versus time-based responses of equal numbers affected performance on the primary task.

Working Memory Performance

The proportion of recall trials on which participants recalled all three words, in any order, was calculated for Phase 1 and for Phase 2 (see Table 1 for the means and standard deviations). These scores were subjected to a mixed ANOVA with age and prospective response condition (no prospective task vs. 6 or 12 intervals) as between-groups variables. The analysis yielded a main effect of age, $F(1, 90) = 30.68, p < .001, MSE = .065, with younger adults performing better than older adults (marginal means of .75 and .56 word sets recalled, respectively). There was also a phase main effect, $F(1, 90) = 91.83, p < .001, MSE = .011, in Phase 2 improved compared with Phase 1. There was also an Age × Phase interaction, $F(1, 90) = 4.05, p < .05, MSE = .011, As in Experiment 1, younger adults improved more, on average, from .67 to .85 compared with older adults who improved from .50 to .61. This again appeared to be an age difference in rate of general learning to perform the working memory task rather than in a cost specific to the addition of the prospective task. The three-way Age × Prospective Response Condition × Phase interaction was not significant, and indeed the gains with practice were essentially equivalent for the two prospective conditions and the control condition in both age groups.

The Prospective Memory Data

Accuracy of responses. The first issue that arises in scoring the time-based data is what constitutes a correct response. Participants were instructed to respond exactly at intervals of 1 min or 2 min of elapsed time. Thus, a correct response could stringently be characterized as one that occurred within 1 s of the target time (e.g., precisely at 1 min, 0 s elapsed time) or, more leniently, as one that occurred within a larger window of time. To address this issue, we calculated a series of dependent measures from the time-based data. A family of five scores with different windows for responding was calculated for each participant with respect to the time-based data. The most stringent window was a 3-s window in which a correct response was defined as one that occurred 1 s before or 1 s after the correct response time and also included a 1-s interval as the correct response time. Additional scores were calculated for intervals ±2, 3, 6, and 9 s, resulting in windows of 5, 7, 13, and 19 s.

Five separate ANOVAs were conducted on these responses. The analyses were a $2 \times 2 \times 2$ between-groups ANOVA with age (young vs. old), prospective interval density (6 intervals vs. 12 intervals), and task load (working memory task present vs. absent) as variables. The analyses yielded remarkably consistent effects, and the main effects for three representative windows are summarized in Table 3. For all five analyses, the main effect of age was significant, with younger adults performing better on the prospective memory task than older adults. An examination of the relatively stringent 3-s criterion to the more lenient 19-s criterion indicates that there were large age differences for both criteria. In the 3-s condition, the means for the younger and older adults were .81 and .43, respectively; whereas for the 19-s window, the means were .95 and .79, respectively. Thus, although the absolute proportion of prospective errors decreased with the more lenient criterion, the older adults nevertheless missed more responses than the younger adults, even when a very large window for responding was used. There was also a main effect of working memory task load in every analysis except for the 19-s window ($p = .07$) such that participants...
Table 3

Significant Main Effects From ANOVAs on Proportion Correct for Three Response Windows and for Deviations in Responding From Target Time (in Seconds)

<table>
<thead>
<tr>
<th>Main effect</th>
<th>Response window</th>
<th>3 s</th>
<th>7 s</th>
<th>19 s</th>
<th>Deviations from target time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>.81 (.23)</td>
<td>.89 (.17)</td>
<td>.95 (.11)</td>
<td>0.91 (.72)</td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td>.43 (.30)</td>
<td>.62 (.34)</td>
<td>.79 (.26)</td>
<td>2.36 (1.71)</td>
<td></td>
</tr>
<tr>
<td>Task load (WM task)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>.69 (.30)</td>
<td>.82 (.26)</td>
<td>1.30 (1.25)</td>
<td>1.87 (1.61)</td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>.57 (.34)</td>
<td>.71 (.32)</td>
<td>1.29 (1.37)</td>
<td>1.34 (1.33)</td>
<td></td>
</tr>
<tr>
<td>Response density</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 responses</td>
<td>.54 (.35)</td>
<td>.69 (.34)</td>
<td>.92 (.26)</td>
<td>1.84 (1.62)</td>
<td></td>
</tr>
<tr>
<td>12 responses</td>
<td>.71 (.28)</td>
<td>.83 (.24)</td>
<td>.92 (.15)</td>
<td>1.41 (1.33)</td>
<td></td>
</tr>
</tbody>
</table>

Note. Standard deviations are presented in parentheses. df for F values are 1 and 103. ANOVA = analysis of variance; WM = working memory.

**p = .06.

performed better on the prospective memory task when they were not also performing on the working memory task.

Interpretation of these main effects is compromised by a significant Age X Working Memory Task Load interaction that occurred for all but the 19-s window analysis (p = .06 in this case). The interaction is presented for the 3-s and 13-s windows in Figure 2. It is clear from Figure 2 that the inclusion of the working memory task did not affect the accuracy of younger adults’ time-monitoring performance. Older adults, however, performed significantly worse on the time-monitoring task when the working memory task was included, suggesting that the performance on the working memory task detracted from their ability to perform the prospective time-based task. Another notable feature represented in the interaction is that younger adults achieved near-perfect accuracy on the prospective task in both control and dual-task conditions at the point in which a 13-s window was used (M = .94 and M = .94 with the working memory task absent or present, respectively). In contrast, as shown in Figure 2, older adults never achieved .90 correct, even with the 19-s window (performance of .86 and .73 with the

![Figure 2](image-url)

Figure 2. A comparison of the proportion of correct prospective time-based responses made as a function of age and working memory (WM) task load (present vs. absent) when the criterion for a correct response is a 3-s or 13-s window.
working memory task present and absent, respectively). It is particularly noteworthy that older adults were not accurately time monitoring in the control condition when their sole task was to pull a lever at an appointed time. This effect holds up no matter how liberal a criterion was used to estimate time-monitoring performance.

Interval density (6 vs. 12 intervals) was not involved in any interactions, but the main effect was significant in all five analyses. As shown in Table 3, participants performed more poorly when they had to respond every 2 min instead of every 1 min. Mean performance in the 3-s window was .54 for 6 intervals and .70 for 12 intervals. In the 19-s window, it was .90 and .81 for 6 versus 12 intervals, respectively.

Another accuracy measure was calculated by determining—for all responses that occurred within a 19-s window—the absolute difference in seconds from the time a participant made a prospective response relative to the time when the response should have occurred. The mean absolute deviation for all prospective responses was calculated for each participant and cast into an ANOVA with age, task load, and interval density as between-groups variables. Results were generally consistent with the window analysis described above and are shown in Table 3. There was a main effect of age, F(1, 102) = 34.18, p < .001, MSE = 1.49, with younger adults having shorter absolute deviations in response times (M = .91 s) than older adults (M = 2.36 s). There was a main effect of working memory task load, F(1, 102) = 6.71, p = .01, MSE = 1.49, and an Age X Working Memory Task Load interaction, F(1, 102) = 10.43, p = .002, MSE = 1.49. The interaction indicated that there was no difference in younger adults' performance when the working memory task was absent versus present (M = .99 s and M = .84 s, respectively), but older adults did perform better in the absent condition compared with the working memory present condition (M = 1.61 and M = 2.97, respectively). No other effects were significant. Interval density approached significance (p = .06), in contrast to the window analysis. As shown in Table 3, there were longer deviations for responses in the 6-interval compared with 12-interval condition. For deviations analysis, only responses occurring within the 19-s window could be included so that responses omitted entirely did not contribute data to the analysis. The marginal effect of density suggests that the density effect observed in the window analyses was largely due to increased omission in the 6-event condition.

Clock-checking behavior. In addition to accuracy measures, we also measured how many times participants checked the clock over the 12-min period. Clock-checking behavior was calculated as follows. For the 12-interval condition, each of the 12 1-min intervals was divided into quartiles of 15 s each. The number of responses that occurred in each quartile was recorded, and an average for each of the four quartiles was obtained for each participant. Similarly, for the 6-interval condition, the four 15-s quartiles of the minute preceding the time when participants should have responded were identified, and the average number of responses made for each quartile for each participant was calculated. These data were then cast into a mixed ANOVA with age, working memory condition, and interval density as between-groups variables and quartile as a repeated measures variable.

The main effects of age, working memory condition, and quartile were significant beyond the .001 level, and all three were involved in interactions. Briefly, the main effects were significant because older adults checked the clock less than the younger adults did (.60 checks vs. .86 checks); there were fewer clock checks in the control condition compared with the memory load condition (.52 vs. .89), and clock checking increased across quartiles (from .34 in the first quartile to 1.38 in the fourth).

There were four two-way interactions as well as a three-way interaction. A three-way Age X Working Memory Task Load X Quartile interaction is presented in Figure 3, F(3, 309) = 17.78, p < .001, MSE = .123. Younger adults in the memory load condition performed differently from participants in the other three conditions. As Figure 3 illustrates, younger adults in the control condition, as well as older adults in both control and memory load conditions, checked the clock relatively infrequently and showed only a slight increase in clock-checking performance in the period immediately preceding the critical response window. Young adults in the memory load condition, however, checked the clock more often from the second through fourth quartile than other participants, with a particularly steep increase in the time period immediately preceding the response window. It appears that young participants made more clock checks when they were also performing the primary task in order to maintain adequate time-based responding.

The two-way interactions that were significant but were subsumed by the three-way interaction discussed above were Age X Working Memory Task Load, F(1, 103) = .123, p < .001, MSE = .123, Age X Quartile, F(3, 309) = 24.36, p < .001, MSE = .123, and Working Memory Task Load X Quartile, F(3, 309) = 9.24, p < .001, MSE = .123. Because they were involved in the three-way interaction, they are not discussed further. There was also, however, an Interval Density X Quartile interaction, F(3, 309) = 4.99, p < .01, MSE = .123. This interaction occurred because there was a difference in performance in the first quartile. Participants were less likely to check the clock in the 12-interval compared with the 6-interval condition (Ms = .23 and .46) in the period furthest away from the response window (Quartile 1). Performance, however, did not differ as a function of interval density across the other three quartiles (Ms = 1.44 and 1.31 in the last quartile).

Individual differences measures. Correlations among the primary working memory task, prospective memory, and the ability measures of vocabulary, speed, and working memory were again computed. Correlations did not differ greatly as a function of which time window criterion was used to compute percentage correct for the time-based task (or, alternatively, whether the absolute difference measure was used).

For younger adults, none of the correlations were significant at a 5% alpha level. For older adults, Phase 1 and Phase 2 working memory performance correlated .47 (p < .01) and .45 (p < .05) with Reading Span, respectively. No other correlations involving the working memory task were significant at the 5% level of confidence. Older adults' prospective memory performance did not correlate appreciably with any cognitive measure. For example, the absolute difference measure for latency to respond correlated −.04 with Reading Span and .02 with Digit Span.

Comparison of primary task data across Experiments 1 and
2. The 128 participants who received the Phase 1 and Phase 2 primary task in Experiments 1 and 2, as well as the prospective task, differed only in terms of the nature of the prospective response that they were required to make. If the prospective task were making different resource demands on participants, performance might be better on the primary task associated with the less demanding prospective task. To investigate this issue, we directly compared the working memory data from participants in Experiments 1 and 2. An ANOVA was conducted on proportion correct with age (young vs. old), prospective density (6 vs. 12 trials), and type of prospective task (event based vs. time based) as between-groups variables and phase (1 vs. 2) as a within-subject variable. The effects of interest are those that involve type of prospective task. Prospective task was involved in an interaction with phase, $F(1, 119) = 5.64$, $p = .02$, $MSE = .009$. The interaction was significant because performance was equivalent between the two groups in Phase 1 (when there was no prospective task) with means of .56 for event based and .59 for time based. However, in Phase 2, when the prospective task was added, performance on the working memory task was poorer for event-based conditions ($M = .65$) compared with time-based conditions ($M = .74$). Thus, primary task performance was significantly better when participants made a time-based response compared with an event-based response.

Discussion

The results from this experiment confirm previous findings that older adults perform poorly on time-based prospective memory tasks (Einstein et al., 1995). The relatively poor performance by older adults occurred even when very liberal standards for what constitutes an accurate response were used and when time intervals were somewhat shorter than those used by Einstein and McDaniel (1996). The mechanisms underlying the poor performance were illuminated by several interactions associated with the accuracy data, frequency of clock-checking data, and by a comparison of the time-based and event-based working memory data.

The accuracy data presented a clear picture of age deficits in prospective performance. Perhaps the most important finding here was the Age × Memory Load interaction. This interaction involved a comparison of prospective performance under conditions in which prospective responding to time was the sole task performed (no memory load) or under conditions in which the working memory task was also performed. Young adults' prospective responding was less than perfect but did not change across the two conditions. In contrast, older adults performed more poorly than younger adults in both conditions, but differentially so when they also performed the working memory task. The larger deficit when the working memory task was present suggests that poor time monitoring is not the sole cause of age differences on prospective tasks, as performance was worse when monitoring was performed in the context of another task.

One possible explanation for the age deficit in time-based responding is that older adults have more limited processing resources available to them to perform tasks. There are numerous studies suggesting that this is the case (Craik & Jennings, 1992; Salthouse, 1992), with working memory capacity and information-processing speed typically nominated as resources that are adversely affected by aging and that limit older adults' performance on cognitive tasks. A resource interpretation suggests that poor prospective performance of older adults occurred because the primary working memory task required proportionately more of the limited resources available to perform on-line tasks for old compared with young. Older adults might then
have insufficient processing resources available to perform the prospective task. However, we found no correlation of measures of either working memory capacity or processing speed with older or with younger adults' prospective memory performance, even though these measures did correlate with performance on the primary working memory task. Moreover, there was evidence that the cost to the primary task was considerably less for time-based responding than event-based responding—a result also not consistent with a simple resource-deficit interpretation. Nevertheless, the general contention of Einstein and McDaniel (1990), that time-based and event-based memory have different characteristics, does appear to be supported by the data.

A second interpretation for the findings is to postulate a vigilance deficit as the mechanism underlying the age difference in time-based prospective memory. In partial support of this, the data for prospective control participants who performed only the prospective task indicated that older adults do not monitor time very accurately, even when that is their sole task. Quite surprisingly, the data indicated that the time-based performance of older control adults was well below ceiling. In the 6-interval and 12-interval conditions for the 3-s window, older adults' performance was .67 correct and .86 correct, respectively. These results, then, suggest that some of the poor performance on the time-based task would occur even if older adults were not engaged in another mental activity. There are some problems with the vigilance hypothesis. First, this explanation accounts only for the overall age deficit in time-based responding and does not account for the interaction of age with presence or absence of the working memory task as displayed in Figure 2. Second, the notion that older adults failed to respond to the prospective task because they could not pay attention to it seems unlikely, extrapolating from work done by Giambra and Quilter (1988). They reported both cross-sectional and longitudinal data regarding age differences in responding to 23 events over 62 min (an event density averaging about 1 event every 3 min; a density somewhat analogous to the 6-interval condition in this study that required participants to respond every 2 min). They found no evidence for age differences in vigilance in either their cross-sectional or longitudinal sample. Parasuraman, Nestor, and Greenwood (1989) found some evidence for decreased vigilance performance in older adults, but their event density was 1 event/4s.

A third explanation, advanced by Einstein and McDaniel (1990) and Einstein et al. (1995), is that older adults' poorer time-based performance may be due to their difficulty in inhibiting irrelevant information from working memory (as suggested by Hasher and Zacks, 1988), causing them to be less able to maintain attention to the prospective task. Such a finding might suggest that older adults have a richer mental life and may be more likely to engage in daydreaming than younger adults; however, the work of Giambra (1989) suggested otherwise. He found that younger adults reported more daydreaming and appeared to engage in more cognitive processing than older adults in unfilled intervals.

A fourth hypothesis is a strategic deficit hypothesis—namely that older adults do not use appropriate strategies for simultaneously performing on the working memory task and monitoring time. One possible source of problems would be metacognitive in nature (Hertzog & Dixon, 1994). Older adults may not monitor prospective failures and adapt to the difficulties created by the working memory task (e.g., Brigham & Pressley, 1988). Faulty task appraisal may also be a factor in that older adults may not know they need to check the clock often in order to respond accurately. Only young participants in the high working memory load condition showed a steep increase in checking the clock in the final quartile, a finding also reported by Einstein et al. (1995). Young adults did not check the clock much in the no working-memory-load condition, but in that case, they also responded accurately. Perhaps the young adults' performance is analogous to a busy executive checking his or her watch very frequently during an important meeting because he or she is aware that it would be easy to forget to leave for the airport at the critical time, given his or her high level of engagement on the primary task of meeting. A metacognitive explanation might also explain why older adults frequently perform well in nonlaboratory prospective studies. Perhaps they avoid getting into the "busy executive" situation in which they have to remember to perform important tasks while simultaneously experiencing a high degree of cognitive engagement.

Besides the poorer time monitoring on the part of older adults, there was also the finding of consistently lower accuracy of keypresses for the 6-interval compared with the 12-interval prospective task. This main effect was not qualified by any interaction and appears to be an overarching aspect of performance on the task. The finding is surprising, in some sense, because the 12-interval task would appear to require more attention than the 6-interval task, yet it was the seemingly "easier" 6-interval task on which participants made more errors. It would seem that participants are more likely to forget about the prospective task and maintain a lower level of vigilance in the 6-interval condition compared with the 12-interval condition. Perhaps an earlier prospective response in the 12-interval condition serves as a cue to maintain vigilance and prepare for the next response, or perhaps older adults have more opportunities to learn how to respond correctly with more events. Because the responses occurred every 1 min in the 12-interval condition compared with every 2 min in the 6-response condition, there is a recency effect for maintaining responding that results in superior performance in the 12-interval condition. This finding again points to the complexity of time-based prospective memory and the need for much more research in understanding its basic properties, as well as the relationship of age to this type of memory.

General Discussion

The two experiments presented here provide convincing evidence that there are age differences in both event-based and time-based prospective memory, even when the retrospective load on a task is low. The present data suggested that time-based prospective memory is adversely affected by aging but that age is also associated with deficits in event-based prospective memory under at least some conditions. Given that there are now a number of demonstrations of age differences in event-based prospective memory in the literature, it does not appear to be valid to argue that event-based prospective memory is unaffected by aging. Instead, as Einstein (1995) recently noted, it may be more profitable to think in terms of the variables that influence when and how event-based prospective memory tasks
produce age differences than in the absolute terms of whether age differences exist.

The inclusion of control conditions in which only prospective responding occurred was unique to this research and was informative in understanding mechanisms underlying age-related differences in performance. We found that performance on only the prospective task in the absence of an on-line working memory task was poor for older adults when it was time based but not when it was event based. Event-based conditions require little self-initiated processing, and older adults responded with total accuracy when this was their sole task, as they were to respond to a single pattern that they easily maintained in working memory. The introduction of the working memory task, however, decreased the likelihood that participants maintained the target pattern in working memory or could attend to the event-based cues when presented. Thus, the differences observed in event-based prospective memory were likely due to difficulties in simultaneously maintaining activation of the target while attending to the cue rather than attending only to difficulties in initiating a response.

In contrast to event-based performance, older adults' performance in the time-based task was poor, even when they did not perform the concurrent working memory task. The basis for the poor performance appears to be that they failed to initiate clock checks regularly, even in control conditions. The failure to check the clock in a condition in which there was no working memory load seems more consistent with the metacognitive explanation than the self-initiated argument posited by Einstein and McDaniel (1990) and Einstein et al. (1995), although as Einstein et al. also noted, other explanations are also viable.

A direct comparison of the working memory data from the event-based and time-based conditions yielded important information that adds further to the puzzle of mechanisms underlying age differences in prospective performance. One would expect that if time-based tasks require more mental effort and self-initiated processing, then working memory performance would be poorer in the time-based condition compared with the event-based condition. The reverse was true; that is, performance on the working memory task was better in the time-based condition compared with the working memory condition for both young and old adults. This finding indicates that the cost of performing the event-based prospective task takes a heavier toll on concurrent working memory performance than does the time-based task. Einstein et al. (1995) made a similar comparison and found no differential effect in their Experiment 3, but they used a question-answering task that tapped general knowledge, which may not have been as sensitive to resource demands as the working memory task in the present study. It is important to note that performance in Phase 1 of the working memory task, when no prospective task was performed, was equivalent among participants in the time-based and event-based condition, so the difference was not due to sampling or other differences between participants in the two studies.

Another finding from these experiments relevant to the issue of interpreting the relationship between working memory resources and prospective memory performance is the low correlations of Salthouse's Reading Span task and the primary working memory task with prospective memory performance in both the event-based and time-based tasks. For young adults, the correlations may have been attenuated in magnitude because of the relatively high levels of prospective performance (mean accuracy at .9 or greater). However, this concern does not appear to apply to the older adults. Indeed, for the event-based task, the correlation of Reading Span with older adults' prospective performance was negative, with higher working memory being weakly associated with lower prospective memory performance. A resource reduction hypothesis would predict that older adults with low working memory capacity would perform more poorly on the prospective task, but this was not the case.

The pattern of results can be reconciled if one views the working memory tasks less as assessing working memory capacity but rather as tasks that engage the central executive (in essence, the processing component of working memory). Standard working memory span measures assess both processing constraints and storage under processing load, and the tasks may be thought of as emphasizing the storage component. As pointed out by Baddeley (1993) and others, one can conceptualize resource-demanding tasks as taxing the central executive—what Shallice (1988) refers to as the supervisory attentional subsystem. This system is responsible for allocating attention to competing action goals and prioritizes enactment of these goals (see also Gathercole & Baddeley, 1993). What may be critical, then, for effective functioning of prospective memory is not working memory capacity, per se, but degree of engagement of the central executive's attentional resources on other tasks.

This finding of a greater cost to perform the working memory task while monitoring events, compared with monitoring time, makes sense if one views the event-based task as requiring constant maintenance of attention to the target pattern in working memory, resulting in some cost to working memory performance. The time-based task, however, permits participants to devote full attention to the working memory task for much of the time, as it is clear that attentional disengagement can occur for the period after a prospective response is made. However, the risk of this disengagement is that a central executive engaged on processing the working memory task may not switch back to the time-monitoring component that is needed to maintain good prospective response rates. This explanation is reminiscent of the test—wait, test—exit cycle for time-based responding proposed by Wilkins and Baddeley (1988). Thus, an important dimension on which time-based and event-based tasks may differ is the amount of continuous sustained attention required for adequate prospective memory. The event-based memory requires relatively more continuous attention, whereas time-based prospective memory requires the central executive to redirect short bursts of attention to the process of time monitoring (as reflected in our patterns of clock-checking behavior). This interpretation is consistent with Einstein and McDaniel's (1990, 1996) argument that the two types of prospective memory are different, but the mechanisms underlying the distinction differ from those they specified.

It should be noted that this study differs from the Einstein and McDaniel (1990, 1996) work in that elderly participants performed more poorly on the working memory task than young adults, whereas Einstein and McDaniel (1990) adjusted the working memory load for elderly participants in an effort to equate processing demands. It may indeed be the case that age differences in event-based memory occur only when a de-
demanding working memory task is used. The results of Kidder et al. (in press) suggested that age differences on event-based responding do not occur when the load of the working memory task is reduced. A working memory load of three was used in the present study. When Kidder et al. compared a load of three items with two items, age differences were found for three (with performance nearly identical to that reported here) but not for two. Moreover, data from the event-based control condition in the present study indicated that under conditions of no working memory load, older adults are able to perform errorlessly on an event-based prospective task. In contrast, the time-based control data suggested that under conditions of no load, older adults still evidence problems compared with younger adults on time-based responding. Moreover, the performance of old and young participants while performing the working memory task looks very similar to that of Einstein and McDaniel’s (1996) participants.

The finding that prospective event density had an effect for time-based but not event-based responding also differentiates the two types of prospective memory. Both young and old adults evidenced poorer prospective memory in the 6-interval time-based condition compared with the 12-interval condition. Participants did not clock check less in the 6-interval condition; in fact, they clock checked more in the first quartile, so it may be the case that it is simply more difficult to estimate 2-min intervals than 1-min intervals, and this estimation difficulty was reflected in the prospective performance. Further investigation in this area seems warranted.

The present experiments certainly lead to a number of additional hypotheses that should be investigated with respect to prospective memory and aging. First, the inclusion of control conditions in which both the primary task and the prospective task were performed alone is critical to the interpretation of data generated in prospective memory studies. Second, the notion that differences in working memory capabilities and self-initiated processing underlie age differences on both types of memory received only limited support in this study, and alternative conceptualizations of prospective memory that are attentional and metacognitive must be considered. Third, the notion that time-based tasks are necessarily more resource demanding may not be entirely accurate, as we found that the performance of the event-based task had a greater toll on working memory performance than did the time-based task. Finally, the hypothesis that event-based memory is insensitive to age differences requires reconsideration of the contextual frame in which event-based memory occurs.

References


Received March 24, 1996
Revision received November 27, 1996
Accepted November 27, 1996