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Effects of aging, planning, and interruption on complex prospective memory

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This study examined the effects of aging, planning, and interruption on complex prospective memory (PM) using a 2 x 2 x 2 between-subjects design. Participants were 80 younger adults (65 females) aged 18–33 years and 80 older adults (70 females) aged 60–75 years. They were randomly allocated to four conditions (viz., no interruption and no planning, interruption but no planning, planning but no interruption, and both planning and interruption) and asked to undertake three PM tasks (time-, event-, and activity-based) while performing an ongoing task (viz., recipe checking and identification) in a simulated home environment. Younger adults were found to perform significantly better than older adults on time- and event-based PM. The opportunity to plan for five minutes was found to improve performances on all three types of PM. Unexpected, external interruptions, on the other hand, were found to reduce performance for time-based PM. Interestingly, planning was found to significantly improve the performance of older adults on time-based PM and to a level similar to that of younger adults. Results of the study have clarified the independent and interactive effects of the three variables on PM and have implications for understanding and enhancing this type of memory.

Keywords: Prospective memory; Aging; Planning; Interruption.

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INTRODUCTION

Prospective memory (PM) involves remembering to perform an intended action at some designated point in the future. Common examples of this type of memory are remembering to buy milk at a shop on the way home from work and remembering to take medication before going to bed. Self-reports of older people point to greater problems with PM with advancing age, but naturalistic studies indicate that older adults perform better on time- and event-based PM tasks (Henry, MacLeod, Phillips, & Crawford, 2004). In the former the participant is required to perform the PM task after the elapse of a certain period of time whereas in the latter the task is to be performed when a stimulus of some sort occurs. The results of laboratory-based studies of PM are more consistent with intuition in showing that younger adults generally perform significantly better than older adults on most PM tasks, with the exception of simple event- and activity-based tasks (e.g., Einstein & McDaniel, 1990; West & Craik, 1999). Activity-based PM tasks require the participant to perform the intended action after an ongoing activity has been completed.

Limitations of both the early naturalistic and the more recent laboratory methods have led some researchers (e.g., McDermott & Knight, 2004) to develop appropriately complex, cognitively demanding, and tightly controlled tasks. In these tasks, participants are required to complete multiple everyday tasks (both ongoing and PM) over longer periods of time and to refrain from using external aids such as diaries. Consistent with these developments, Kliegel, McDaniel, and Einstein (2000) proposed a new paradigm they termed "complex PM". This involves remembering and executing multiple PM tasks according to a set of rules while undertaking a number of ongoing tasks. Increasing the complexity and the ecological validity of the paradigm is seen as an important step in PM research and provides justification for the methods developed in the current study.

The main purpose of the present study was to examine the effect of aging on PM using a complex PM paradigm. In addition, it was concerned with how planning and interruption affect PM. According to McDaniel and Einstein (2011), planning in prospective memory is rarely investigated. This is because most experimental PM tasks are simple and do not require or benefit from planning. One exception is a study by Kliegel et al. (2000) which utilised a complex PM task to compare plan formation, retention, and execution in younger and older adults. Results of the study indicated that there were significant age differences in quality, initiation, and execution of the plans. In contrast, no difference was found for plan retention and the fidelity with which the plan was carried out. To date, however, no study has directly examined whether providing participants with time to plan improves PM performance or whether there is an age difference in the benefits of planning on PM performance.

Few studies have directly addressed the influence on PM of an unexpected, external interruption, such as a person-initiated interruption unrelated to the ongoing task (Mantyla & Sgaramella, 1997; McDaniel, Einstein, Graham, & Rall, 2004). Early work on how PM performance may be affected by an interruption was conducted by Mantyla and Sgaramella (1997). These authors reported that cue items associated with interruption were better reminders than were items that were associated with completion. They accounted for this counter-intuitive finding by suggesting that interruption of an ongoing activity facilitates subsequent PM performance by increasing the level of activation of the intention.

Einstein, McDaniel, Lyle, Pagan, and Dismukes (2003) and McDaniel et al. (2004) used a delay-execute PM task, in which performance needed to be delayed for a period of time (e.g., 5, 15, or 40 s) after the cue was encountered, to investigate the effects of an interruption. Participants were engaged in a series of 1-minute computer-based tasks that lasted over a 32-minute period and involved the answering of trivial questions, solving arithmetic problems, and choosing correct synonyms. Participants were told that whenever they saw a red screen they should press the slash key on the keyboard but not until they completed the current task and the next task was presented (delay-execute PM task). The appearance of a message on the screen "GO TO FOLDER" signalled the interruption and meant that participants were to complete a pattern-comparison task until the message disappeared. Both experiments found that delay length did not significantly affect performance but that interruptions, regardless of their length (10 or 20 s), produced significant decrements in performance relative to a delay alone.

In explaining their findings, Einstein et al. (2003) and McDaniel et al. (2004) argued that humans have a finite amount of cognitive resources to perform any task and these resources must be divided when there is more than one task to be performed. With their procedure, resources had to be divided among the ongoing task, monitoring for PM cues, performing PM tasks, and responding to interruptions. Interruptions divert available resources from the ongoing task and PM tasks and this, they argued, leads to a decline in performance. Delays do not have the negative impact that interruptions do because, unlike interruptions, delays allow time for memory checks on incomplete intentions. PM performance may be further compromised when the interruption passes and attention is redirected to the old tasks. Einstein and colleagues proposed that it is difficult to reactivate the entire set of task demands upon return and only the primary goals of the ongoing task may be reactivated immediately whereas secondary goals may be forgotten, at least initially.

Interruption may also be expected to have a more adverse effect on older than younger adults' PM performance. Acccording to Hasher, Zacks, and May's inhibition theory of aging (1999) inhibitory control declines as frontal-lobe function degrades with advancing age, limiting the capacity to filter out or ignore irrelevant stimuli. More specifically, this theory implies that older adults may become more absorbed in an interruption and may also find it more difficult to remove it from working memory after it has passed. This in turn could affect the performance on any ongoing or PM tasks.

The present study aimed to investigate the effects of aging, planning, and interruption on the performance of three PM tasks within a complex PM paradigm. Unlike experimental paradigms that use computerised dual tasks, the ongoing task (viz., planning a meal and choosing a recipe) and setting (viz., a simulated kitchenette and lounge room) of the present study are both complex but familiar to older as well as younger individuals. In addition, instead of asking the participants to perform just one PM task at a time as in other studies, participants were given three PM tasks. It was hypothesised that younger adults would perform better than older adults on all three PM tasks. This is because older adults have fewer cognitive resources adequately to encode, plan, and execute all three PM tasks, given the complex PM paradigm adopted in the present study. Planning was expected to improve prospective remembering. A significant two-way interaction between age and planning was expected, if older adults benefit more from planning than younger adults. Because the interruption in the current study was unexpected, required immediate attention, and taxed working memory capacities and cognitive resources, it was hypothesised that PM performance would be reduced in those exposed to an interruption. A significant two-way interaction between age and interruption was expected, if older adults are more affected by the effects of interruption than younger adults.

METHOD

Design

The study used a 2 (Age) x 2 (Planning) x 2 (Interruption) between-subjects design. Younger and older adults completed PM tasks under one of four conditions: no interruption and no planning (Condition 1); interruption but no planning (Condition 2); planning but no interruption (Condition 3); and both interruption and planning (Condition 4).

Participants

A total of 160 adults participated. The younger group comprised 65 female and 15 male undergraduate psychology students aged 18–33 years ($M = 21.44$

years, *SD* = 4.53 years) who were given course credit. The older group comprised 70 females and 10 males aged 60–75 years (*M* = 68.23 years, *SD* = 4.13 years) who were recruited from the community and participated voluntarily. Younger adults had significantly more years of education than older adults, but older adults had higher estimated IQs (using NART-2; Nelson & Willison, 1991) than their younger peers. Both groups rated their health as good, and scored well above the cut-off of 30 for dementia (using Telephone Interview Status–Modified; Welsh, Breitner, & Magruder-Habib, 1993). Nevertheless, older adults reported having significantly more medical conditions and taking more medications than younger adults. There were no differences across the four experimental conditions on any of these variables for either the younger or older groups (see Table 1).

Apparatus and materials

"Home-like" laboratory. The study was conducted in a "home-like" laboratory, with two interconnecting rooms (a living room and a kitchen; see Figure 1). The living room contained a couch, chairs, television, bookcase, and coffee table. A videocassette recorder (VCR) was placed in the bookcase. The kitchen contained cupboards, refrigerator-freezer, telephone, and table

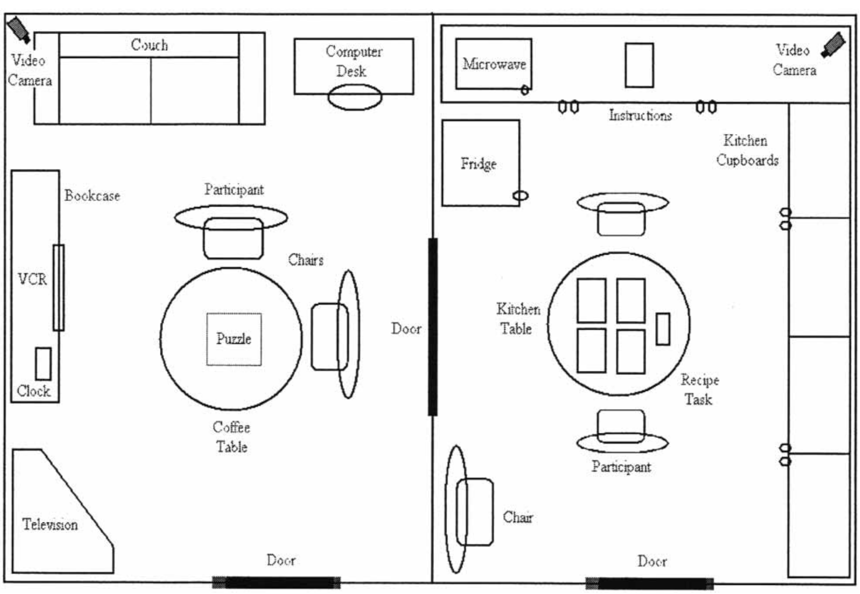

Figure 1. Floor plan of the home-like laboratory. Note: The door connecting the two rooms was always open.

TABLE 1
Demographic information for each of the four conditions by age group

Conditions	*Younger adults*								*Older adults*							
	1		*2*		*3*		*4*		*1*		*2*		*3*		*4*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age	20.35	4.41	20.70	2.97	22.25	4.97	22.45	5.57	69.30	4.28	68.85	3.10	66.70	4.29	68.05	4.52
Years of education	13.05	1.09	13.60	1.69	13.45	1.35	12.70	1.03	11.10	3.37	12.65	4.38	13.00	3.69	12.10	3.02
Self-health rating	4.25	0.91	4.65	0.74	4.60	0.60	4.55	0.68	4.35	0.67	4.65	0.81	4.45	0.99	4.55	0.82
Number of health problems	0.15	0.48	0.10	0.44	0.00	0.00	0.20	0.41	1.30	1.30	1.30	1.17	1.35	1.34	1.10	1.37
Number of medications taken	0.25	0.58	0.25	0.55	0.15	0.36	0.40	0.68	1.90	1.02	2.10	0.96	1.60	1.27	1.65	1.13
NART-2 (Predicted FSIQ)	101.30	5.77	105.70	5.63	104.60	7.52	105.65	7.23	115.15	11.81	113.35	10.56	114.00	9.55	117.95	6.48

Condition 1 = no planning and no interruption, Condition 2 = interruption but no planning, Condition 3 = planning but no interruption, Condition 4 = interruption and planning; $n = 20$ for each condition in each age group.

and chairs. Separate video cameras were mounted in the kitchen and the living room to allow the experimenter to observe participants' performance from an adjacent room.

Ongoing task. Participants were asked to sit at the kitchen table and use a recipe book and a price catalogue to decide which recipes were the most time- and cost-effective. Their decisions were based on data gathered during a series of steps (described below). Older adults took approximately 1.5 hours, and younger adults approximately 1 hour to complete this task.

As a first step, participants were instructed to inspect all the cupboards and the refrigerator-freezer for ingredients on a checklist and, once located, to check off the items on the checklist. The second step involved searching the 11 recipes in the recipe book for ingredients required to prepare the dishes. Individuals were instructed to list on a different form, the Recipe Outcomes Form (ROF), the ingredients required for the recipes that were not in the kitchen. The third step was to obtain the prices for all the recipes from a price catalogue. By locating the prices of the ingredients listed on the ROF, participants were able to calculate the total cost for each recipe, which they were instructed to write in the relevant section of the ROF. The fourth step involved entering on the ROF the combined preparation and cooking times for each recipe. The final step involved deciding which of the 11 recipes were the cheapest and the quickest to prepare.

PM tasks. Participants were also required to complete three PM tasks concurrently with the ongoing task. The first was event-based and embedded in the ongoing task. Participants were required to place a white sticky dot (5 mm in diameter) on the top right-hand corner of any recipes that contained dairy products (the PM cue). To avoid providing participants with a constant reminder of this PM task, the dots were hidden from view on the inside back cover of the recipe book. The explanation for placing the dot on the recipes was that one of the guests coming to dinner may be allergic to dairy products.

Participants were instructed to work on one recipe at a time and not to turn back to previous recipes or skip forward to upcoming ones, so that PM cues would appear at planned intervals. Four of the 11 recipes (viz., 4, 7, 9, and 11) contained dairy products. Each dairy product was different (viz., for recipe 4, butter; for recipe 7, milk; for recipe 9, yogurt; and for recipe 11, cheese).

A score of two was allocated for placement at the correct time of a white dot on a recipe that contained dairy. One point was allocated for late placement. A score of zero was allocated when a white dot was not placed on a diary recipe. The maximum score for this task was eight.

The second PM task was time-based and not embedded in the ongoing task. It required participants to press the pause button on the VCR every 5 min as determined from the clock next to it, on the pretext that television programmes were being monitored for unacceptable levels of violence. Participants were required to press pause at 5 min intervals until the ongoing task was completed. The VCR and clock were located in the living room, requiring participants to turn 90 degrees to the left to view the clock and leave the kitchen to press pause.

The scoring of the time-based task was guided by the procedure adopted by Einstein, McDaniel, Richardson, Guynn, and Cunfer (1995). Those who pressed pause on the VCR within 10 s before or after the 5 min interval were allocated 4 points. Those who pressed pause after 10 s but within 20 s before or after the 5 min interval were allocated 3 points, those who pressed pause after 20 s but within 30 s before or after the 5 min interval were allocated 2 points, and those who pressed pause after 30 s, 1 point. Those who pressed pause outside the 60 s window or who failed to press pause were given a score of 0 for the interval. An average (rather than a total) score based upon each participant's overall performance was used as the dependent variable because the number of opportunities for pressing pause varied among participants.

The third PM task was activity based. It involved asking participants to surrender a personal possession at the beginning of the experiment and to ask for it back at the end. The personal possession was either a wrist watch (if participants wore one) or a mobile phone. All participants had one or the other or both. Participants were told this request was to prevent them from using other means than the designated clock to monitor time. A score of 2 was allocated if participants asked for the possession immediately upon the experimenter's return at the end of the experiment; a score of 1 was allocated if participants asked for the possession after a prompt, and a score of 0 was given if the possession was not asked for even after the prompt.

Post-task test and interview. When participants had completed the tasks they were asked to recall all the instructions. A structured interview was also conducted to identify processes used by participants in remembering and completing the PM tasks.

Procedure

Participants were randomly allocated to one of the four experimental conditions after completing the dementia screening and health criteria required. After obtaining the participant's consent, experimental instructions were presented verbally. A written summary of the main tasks, excluding the PM tasks, was placed on the bench top to reduce the load on retrospective memory. This summary was available to all participants at all times.

Condition 1: No interruption and no planning. Participants in this condition were asked to complete a jigsaw puzzle before commencing the ongoing task. They were told to stop working on the puzzle when they heard the telephone ring (which occurred after 5 min) and to move onto the ongoing task. Participants performed the ongoing and PM tasks without any further contact with the experimenter until they had finished. On completion, they were joined by the experimenter and had the opportunity to ask for the return of their personal possession. They were then taken to another room for the post-task test and interview.

Condition 2: Interruption but no planning. Instructions in this condition were similar to those in Condition 1. However, participants were subjected to two interruptions during the ongoing and PM tasks. The first occurred when participants reached the first recipe with a dairy product (viz., recipe 4), and was timed for 5 s after participants turned to the target page. The experimenter was able to interrupt at this precise time by monitoring from the assessment room.

To ensure the plausibility and validity of the interruption, a procedure refined in a pilot study was adopted whereby a mobile phone was placed out of view, behind the door that connected the living room and the kitchen. When participants turned to the first recipe with a dairy product, the experimenter rang the mobile phone, at which point all participants were observed to stop what they were doing. When the ringing stopped, the experimenter entered the room, expressing feigned surprise at the noise, and asked participants if they knew what it was. Discussion of the source and location of the noise ensued. After retrieving the phone from behind the door, participants were asked if it belonged to them. None of the participants claimed the phone as their own, and the pretence was made that it must have been left there by a previous participant. Participants were then asked to continue the task. In total, the interruption lasted 2 min.

Based on results of a pilot study, it was decided that two interruptions were needed. Therefore, a second interruption was carried out at 5 s after the participants turned the page to the next recipe with a dairy product (viz., recipe 7). On this occasion, the experimenter entered the kitchen, apologised for the interruption, and explained that the participant, who had supposedly forgotten the mobile phone, had just called in an attempt to locate it. The experimenter was therefore checking the room to make sure nothing else had been left behind. This interruption lasted for approximately 1 min.

Condition 3: Planning but no interruption. This condition was similar to Condition 1 with the exception that the puzzle task was replaced with 5 min of planning. Participants were told to "spend the next five minutes writing down as many of the instructions that I gave you that you can remember. Also, try to write down a plan of how you will perform all of these tasks. Perhaps you want to visualise me giving you all of the instructions." They were told that when they heard the telephone ring (after 5 min), they should fold the piece of paper in half and place it outside the door. As with participants in Condition 1, participants in this condition completed the ongoing task and PM tasks without any further contact with the experimenter until the tasks were completed.

Condition 4: Interruption and planning. Participants in this condition were allowed 5 min to plan (as in Condition 3) and were also exposed to the two interruptions (as in Condition 2).

RESULTS

Retrospective memory and the ongoing task

At the post-task interview, 1 younger and 13 older adults failed to recall the event- and/or activity-based PM tasks, even after being prompted. Of these participants, eight were from Condition 2, four from Condition 1, and two from Condition 3. For the time-based task, all these 14 participants recognised the instructions once they were mentioned by the experimenter and recalled what they were required to do. For the three PM tasks, ANOVAs were conducted with and without these participants and the conclusions were basically the same. Because the PM scores of these 14 participants were probably contaminated by poor retrospective memory, the ANOVA results without these participants are included here. In terms of ongoing task performance, the cheapest and quickest recipes were correctly identified by all participants, indicating familiarity and engagement in the task.

Event-based (dairy product) task

ANOVAs were used to analyse all PM scores. Table 2 summarises the mean scores for the eight experimental groups for the event-based task. There was a significant Age main effect. Younger adults ($M = 5.06$, $SD = 3.13$, $n = 79$) remembered to place white dots on recipes with dairy products significantly more than older adults ($M = 3.88$, $SD = 3.27$, $n = 67$), $F(1, 138) = 12.51$, $p < .05$, $\eta^2 = .08$. Although, as expected, participants who were interrupted ($M = 4.19$, $SD = 3.31$, $n = 72$) had lower scores than those who were not ($M = 4.84$, $SD = 3.16$, $n = 74$), the Interruption main effect failed to reach statistical significance, $F(1, 138) = 3.71$, $p = .056$. A significant Planning main effect was found for the event-based task, $F(1, 138) = 102.06$, $p < .05$, $\eta^2 = .43$. Participants who had the opportunity to write a plan ($M = 6.36$,

TABLE 2
Mean scores on the event-based task by age group, interruption, and planning

	Younger adults						*Older adults*					
	Planning						*Planning*					
Interruption	*Yes*			*No*			*Yes*			*No*		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Yes	20	6.70	1.86	19	2.26	2.68	20	5.45	2.89	13	1.23	2.61
No	20	7.00	2.27	20	4.15	3.08	18	6.33	1.91	16	1.31	1.77

SD = 2.27, *n* = 78) had significantly higher scores than those who had not (*M* = 2.25, *SD* = 2.58, *n* = 68,). There were no significant two- or three-way interactions.

Time-based (VCR) task

Table 3 summarises the mean scores for the eight experimental groups for the time-based task. There was a significant Age x Planning interaction, $F(1, 138) = 15.15$, $p < .05$, $\eta^2 = .10$. Simple main effect analyses revealed that, in the no-planning condition, younger adults had significantly higher scores for remembering to pause the VCR (*M* = 3.34, *SD* = 0.46, *n* = 39) than older adults (*M* = 2.73, *SD* = 0.61, *n* = 29), $t(66) = 4.67$, $p < .05$. However, there was no statistically significant difference between younger (*M* = 3.76, *SD* = 0.27, *n* =40) and older adults (*M* = 3.65, *SD* = 0.26, *n* = 38) on the "pausing" task when planning beforehand was provided, $t(76) = 1.71$, $p = .09$. Although the performance of both groups of participants increased with planning, the increase in performance for the older adults was much greater.

Further, there was a significant Interruption main effect. Participants who were interrupted (*M* = 3.33, *SD* = 0.53, *n* = 72) performed significantly more poorly than those who were not (*M* = 3.48, *SD* = 0.54, *n* = 74), $F(1, 138) = 8.26$, $p < .05$, $\eta^2 = .06$.

There were no significant three-way interactions.

Activity-based (possession) task

Table 4 summarises the mean scores for the eight experimental groups on the activity-based task. A significant Interruption x Planning interaction was found, $F(1, 138) = 4.77$, $p < .05$, $\eta^2 = .33$. Simple main effect analyses revealed a significant difference between those in the interruption condition (*M* = 0.34, *SD* = 0.48, *n* = 32) and those in the no-interruption condition (*M* = 0.64, *SD* = 0.54, *n* = 36) when the groups had no opportunity to plan, $t(66) = -2.36$, $p < .05$. However, the opportunity to plan eliminated the difference between the interrupted (*M* = 1.3, *SD* = 0.56, *n* = 40) and the uninterrupted group (*M* = 1.21, *SD* = 0.62, *n* = 38), $t(76) = 0.66$, $p = .51$. There was no significant difference between younger (*M* = 0.90, *SD* = 0.63, *n* = 79) and older adults (*M* = 0.91, *SD* = 0.73, *n* = 67), $F(1, 138) = 0.32$, $p = .57$. There were no significant three-way interactions on the activity-based task.

Post-task interview

How participants remembered. The interview revealed that participants who successfully remembered the PM cues did so by consciously keeping

TABLE 3
Mean scores on the time-based task by age group, interruption, and planning

	Age group											
	Younger adults						*Older adults*					
	Planning						*Planning*					
Interruption	*Yes*			*No*			*Yes*			*No*		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Yes	20	3.71	0.27	19	3.25	0.44	20	3.56	0.27	13	2.56	0.51
No	20	3.80	0.26	20	3.43	0.47	18	3.76	0.22	16	2.88	0.66

TABLE 4
Mean scores on the activity-based task by age group, interruption, and planning

	Age group											
	Younger adults						*Older adults*					
	Planning						*Planning*					
Interruption	*Yes*			*No*			*Yes*			*No*		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Yes	20	1.35	0.48	19	0.47	0.51	20	1.25	0.64	13	0.15	0.38
No	20	1.10	0.64	20	0.65	0.49	18	1.33	0.59	16	0.63	0.62

the intention in mind and actively searching for the cues, or reported that "it just came into mind" at the right time. Overall, most participants (97%, $n =$ 142) reported that the time-based task was consciously kept in mind rather than that "it just came into mind". By contrast, in both the event-based (except where planning time was given) and the activity-based tasks, the majority of participants who remembered to perform these two tasks (57% and 78% respectively; $n = 62$ and 82) said their remembering was less conscious, and that thoughts just "popped into mind". The difference between reported strategy use for each task was significant, $\chi^2(2) = 7.81$, $p < .05$, with the time-based task being held in mind significantly more than the activity-based task, $\chi^2(1) = 82.03$, $p < .05$, and the event-based task, $\chi^2(1) = 66.14$, $p < .05$. The event-based task was more likely to be consciously held in mind than the activity-based task, $\chi^2(1) = 17.74$, $p < .05$.

Reasons for forgetting. Participants reported three main reasons for forgetting: a weak cue that did not trigger the PM tasks; distractions from other tasks; or poor encoding and lack of strategy use. Across both age groups and all conditions, the event-based task was reported to be forgotten most frequently (71% of participants who forgot to put a white sticky dot on at least one recipe with a diary product; $n = 70$), because the cues were too weak to trigger the task than for other reasons, $\chi^2(1) = 27.18$, $p < .05$. The time-based task was reported to be forgotten most frequently (80% of participants who forgot to press the VCR on time every time; $n = 98$), because of distractions from other tasks than for other reasons, $\chi^2(1) = 44.46$, $p < .05$. The activity-based task was reported to be forgotten most frequently (52% of participants needed a prompt to ask for their personal item or failed to ask for the item; $n = 62$), because of a poor use of or a failure to use strategies than for other reasons, $\chi^2(1) = 10.22$, $p < .05$.

Types of planning. The elaborateness of plans made by those in the planning conditions was determined by counting the number of PM tasks they wrote down, and the number of points they made regarding how to remind themselves about the PM tasks. No significant differences between younger ($n = 40$) and older adults ($n = 38$) were found for the former, $t(76) = 1.44$, $p = .15$, or the later, $t(76) = -0.48$, $p = .63$.

DISCUSSION

The present study investigated the effects of age, planning, and interruption on PM using a complex PM paradigm in a simulated home environment. The hypothesis that younger adults perform significantly better than older adults on PM tasks was partially supported. Younger adults outperformed older adults on the time- and event-based tasks, but not on the activity-based task.

The hypothesis that planning improves PM was supported. Participants who were given a 5 min planning period before the ongoing and PM tasks performed significantly better on all three PM tasks than those who were asked to solve a puzzle for 5 min. There was, however, a significant two-way interaction between age and planning for the time-based PM task indicating that older adults may benefit more than younger adults from the 5 min planning opportunity on this PM task.

The hypothesis that interruption significantly reduces PM performance was supported for only one of the three types of PM task, namely, time-based, although the effect of interruption on the event-based task just failed to reach statistical significance ($p = .056$). There was a significant two-way planning by interruption interaction for the activity-based PM task indicating that having 5 min to plan reduces the effect of unexpected external interruptions.

Age-related differences on time- and event-based PM tasks have been found in previous studies, particularly those that used computerised experiments (Einstein et al., 1995; Kliegel et al., 2000, Kliegel, Ramuschkat, & Martin, 2003; Mantyla, 1994; McDaniel et al., 2004; West & Craik, 1999). In the present study, no significant age difference on the activity-based task was found. Compared to time- and event-based PM, activity-based PM is considered less cognitively demanding because more cognitive resources are available to perform the PM task after the completion of the ongoing task. Thus, it has been found not to be as affected by aging as the other types of PM (e.g., Kliegel et al., 2000). Several studies have shown that freeing up resources at retrieval benefits PM performance (Marsh & Hicks, 1998; McDaniel, Robinson-Reigler, & Einstein, 1998; McDaniel, Einstein, Stout, & Morgan, 2003). The better performance on the activity-based PM task could also be because the PM cue for this task (viz., the participant's watch or mobile phone) had more personal significance and consequences if forgotten. One other possibility is that if an older group than the one employed in this study was used, an age difference would emerge.

Significant effects for planning have not been reported previously for complex PM tasks. In the present study all three types of PM were found to benefit significantly from a short planning period at the outset. This may reflect the value of goal clarification and strategising or, more simply, the rehearsing of the links between future cues and actions.

On the time-based PM task but not on the event- and activity-based PM tasks, a significant two-way age by planning interaction was found. Under the no planning condition, the younger group performed significantly better than the older group on the time-based task, but when both groups were given a 5 min opportunity to plan, the performance of older adults improved to a level similar to that of the younger adults. Why this effect was not seen with the event- and activity-based tasks is unclear. The time-based task was the one that participants reported at interview to be the one that they were most likely to "keep in mind". However, reported elaborateness of planning did not differ as a function of age, unlike the effect reported by Kliegel et al. (2000). If replicated, the finding with the time-based task suggests that a simple tactic such as asking older individuals to remember and write down what they have to do can improve their PM performance to a similar level as younger adults within a complex PM paradigm.

The effect of interruption on the time-based task found here agrees with the findings of Einstein et al. (2003) and McDaniel et al. (2004) using a delay–execute PM task and, for this task at least, is consistent with a limited resources interpretation of PM performance. When resources are depleted by the need to manage an interruption there are fewer available for performance of the main task. There was, however, no interaction with age for any of the three PM tasks, which would have been expected in terms of the inhibition theory of aging advanced by Hasher, Zacks, and May (1999). According to this theory older adults should have found the interruption more challenging and disruptive than younger adults, but this does not appear to be the case. The relevance of the inhibitory interpretation is further thrown into doubt by the significant interaction between interruption and planning for the activity task. The detrimental effect of interruption was overcome by having participants plan for 5 min. This implies that explicit advanced preparation can offset the effects of distraction. Consistent with Einstein et al. (2003) and McDaniel et al. (2004) the findings suggest that it is goal maintenance rather than interference by irrelevant stimuli that is important for task performance. In effect, planning may offset the detrimental effects of interruption by facilitating goal maintenance. Be that as it may, the absence of a significant interaction effect with age and the absence of main effects for event- and activity-based tasks indicates the need for further examination of the effects of interruption on PM. For example, it could be that the effects of interruptions which occur during activity-based PM tasks such as our recipe task could be minimised because the interruption unintentionally draws more attention to the activity.

Although the present study has overcome some of the pitfalls associated with the naturalistic and experimental PM paradigms, it is not without limitations. First, given that the participants were required to perform a number of ongoing as well as PM tasks that are self-paced, experimental control was not as tight as in less naturalistic settings. Although the experimenter was able to monitor and time the interruption, it is possible that some PM failures could be caused by conflicts of the PM task schedules. Second, although it is important to demonstrate that planning can improve the three types of PM, the design and procedures of the study did not readily allow the underlying mechanisms of these improvements to be determined. Third, the interruption manipulation developed for this study might not have been strong enough to demonstrate main or interactive effects. Finally, the PM tasks used were complex and varied in a number of ways other than the type of PM involved, and this precludes simple comparisons between the tasks.

Overall, this study has shown that performances on event-, time-, and activity-based PM tasks can be measured using a complex PM paradigm without compromising experimental control. The use of this new paradigm is important and necessary because, compared to computerised experimental paradigms, it uses everyday tasks that older adults normally engage in at home or in the community. In addition, results of this study have reinforced the important role of planning in facilitating prospective remembering. Furthermore, in showing that older adults' performance on a time-based PM task could be increased to the same level as younger adults by simply having 5 min of planning time, this study has provided promising evidence to support the adoption of this technique to improve PM in older adults.

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