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Prospective Memory in Children: The Effects of Age and Task Interruption

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Prospective memory (PM), remembering to carry out a task in the future, is highly relevant to children's everyday functioning, yet relatively little is known about it. For these reasons the effects of age and task interruption on PM were studied in 3 experiments. Children aged 4, 5, and 7 years were asked to name pictures in stacks of cards (the ongoing task) and to remember to do something when they saw a target picture (the PM task). Significant age differences were identified, but age explained only a small amount of variance. As predicted, children in the no-interruption condition performed significantly better than those who had to interrupt the ongoing activity in order to carry out the PM task. An additional finding was that no relation was detected between performance on prospective and retrospective memory tasks. Taken together, these findings provide support for current models of PM and identify ways to assist children's PM.

One of the recent distinctions drawn in research into memory is the difference between retrospective and prospective memory (Meacham & Leiman, 1982; see also Brandimonte, Einstein, & McDaniel, 1996). Retrospective memory refers to remembering information acquired in the past, such as remembering the contents of a book, people's names, or what one did on the previous day. In contrast, prospective memory refers to remembering to carry out an intended action at some point in the future, such as remembering to pass a message to a friend, make a phone call at 2 p.m., or take a pill after breakfast.

Prospective memory failures are quite common and may constitute 50–70% of memory failures occurring in everyday life (Crovitz & Daniel, 1984; Mateer, Sohlberg, & Crinean, 1987; Terry, 1988). It is interesting that when adults comment on their own or their children's memory lapses, they "often appear more concerned with instances of forgetting to carry out actions than with forgetting information about the past" (Meacham, 1977, p. 291). This is because prospective memory is a crucial component of our everyday activities; a failure to realize that one had intended to do something at a particular moment may have unpleasant consequences by seriously disrupting one's day-to-day life at home, work, or school (see Meacham, 1982; Winograd, 1988).

Therefore, an investigation of mechanisms and processes that lead to successful prospective memory performance in adults as well as children has both theoretical and practical importance. Indeed, by shedding some light on retrieval processes involved in prospective memory we could (a) substantially enhance the understanding of memory processes and (b) develop a set of guidelines and/or memory aids aimed at remedying the frequent occurrence of prospective memory failures in a variety of everyday settings.

Although prospective memory research has been gradually expanding over the past 20 years (particularly since 1990, when some simple and efficient laboratory methods were developed; see Einstein & McDaniel, 1990), only a handful of studies exist on prospective memory in children (see Beal, 1988; Ceci, Baker, & Bronfenbrenner, 1988; Ceci & Bronfenbrenner, 1985; Guajardo & Best, 2000; Kerns, 2000; Meacham & Colombo, 1980; Meacham & Dumitru, 1976; Passolunghi, Brandimonte, & Cornoldi, 1995; Somerville, Wellman, & Cultice, 1983). Moreover, these studies have been conducted over considerable time intervals by various researchers who explored different variables with different tasks, and as a result, there is no coherent picture of the development of prospective memory skills in children. The scarcity of research about developmental aspects of prospective memory is reflected in the absence of a chapter on this topic in the first book on prospective memory (Brandimonte et al., 1996) as well as in a special issue of *Applied Cognitive Psychology* (Kvavilashvili & Ellis, 2000) on prospective memory.

The paucity of findings is in marked contrast to the large (if not huge) research literature on children's retrospective memory, and this disparity is particularly striking when one considers the relevance and importance of prospective memory in terms of everyday activities. For example, children often have to remember to pass messages, perform various chores at home, take things to school, brush their teeth, and so on (Nerlove, Roberts, Klein, Yarbrough, & Habicht, 1974). Moreover, several authors have expressed the view that in order to successfully cope with a variety of everyday situations, the early development of prospective memory skills may be particularly important. For example, Winograd (1988) has noted that

> prospective remembering might be expected to manifest itself early in development because it is a means to an end. If one remembers to

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> perform an activity one is rewarded. This is not the case for retrospective remembering by and large, until schooling begins with its demands on memorization of arbitrary information. (p. 351)

Meacham and Colombo (1980) have even said that "children's attempts at prospective remembering may be an important precursor to the development of strategies for retrospective remembering" (p. 299).

It is interesting that these ideas have found initial support in a naturalistic study of Somerville et al. (1983) in which 2-, 3-, and 4-year-old children were assigned to different reminding tasks by their caregivers over a 2-week period. Two important findings emerged from this study. First, even with long delays of several hours, children as young as 2 years of age were successful at prospective remembering on at least 50% of the relevant occasions if the task was of high interest to them (e.g., "remind me to buy some candy when we are in the shop tomorrow"). Second, there was no effect of age. Two-year-olds performed as well as 4-year-olds on prospective memory tasks.

In light of these issues it is obvious that the experimental investigation of prospective memory in children is both important and timely. Of particular interest are, of course, the effects of age to provide information on the developmental trajectory of this form of memory. In order to develop a broader understanding of prospective memory, we also wanted to investigate the effects of variables that have been identified by theoretical models as crucial for successful prospective memory. Thus, according to a recently proposed model (Kvavilashvili & Ellis, 1996), interruption of an ongoing activity is an important feature of most everyday prospective memory tasks. Very often people need to interrupt the activities in which they are currently engaged when the appropriate time or occasion for the execution of an intended action arrives (Einstein & McDaniel, 1996; Maylor, 1996; Morris, 1992; Shallice & Burgess, 1991). For example, one may need to interrupt watching TV in order to make a phone call at a particular time. On some occasions, however, such interruption may not be necessary, as one may wish to make an intended phone call after finishing watching TV. In other words, one has to remember to do something after one activity has finished and before another one has started (i.e., during the gap that occurs between the two consecutive activities). Task interruption may pose enhanced attentional demands on the individual, which is likely to result in a failure to remember one's intention on time (Kvavilashvili & Ellis, 1996; see also Cockburn, 1995).

Finally, there is an important issue of the relationship between children's prospective and retrospective memory. There are several studies on adults that have examined the correlations between these two types of memory (e.g., see Einstein & McDaniel, 1990; Huppert & Beardsall, 1993; Kvavilashvili, 1987; Maylor, 1990), and they have generally failed to obtain significant results. However, it is possible that a different pattern of results will emerge in young children. For example, there is a possibility that these two types of memory are initially related, but in the course of development, they become unrelated (Guajardo & Best, 2000, provide initial support for this conjecture).

Thus, we designed this study primarily to investigate the following three issues in relation to prospective memory. First, we wanted to study the effects of age on event-based prospective memory, which involves remembering to do something in response to a certain event (e.g., remembering to mail a letter when seeing a mailbox). Although several different types of prospective memory tasks have been identified (e.g., see Einstein & McDaniel, 1990; Kvavilashvili & Ellis, 1996), event-based tasks have been a major focus of research on the adult population; therefore, in the present study we chose to concentrate on this form of prospective memory. Second, we wanted to test our hypothesis about the effects of task interruption on prospective memory. Finally, we also wanted to look at the relationship between children's prospective and retrospective memory performance.

To achieve these three aims, we used a simple but engaging laboratory task that was specifically developed for these purposes. The children were engaged in a "game" of naming a series of picture cards (the ongoing task) and, in addition, they had to remember to hide the cards on which there was a picture of an animal (the prospective memory task). There were four stacks of cards. Prior to naming each stack, children were asked to draw a picture. This was done to increase the children's involvement in the procedure, to introduce some variability into the experimental session, and to avoid ceiling effects.

Task interruption was manipulated by presenting the target pictures either in the middle of the stack of cards or as the last picture in the stack. The former required the interruption of the ongoing card-naming task in order to hide the target card. No such interruption was needed in the latter case, because it was obvious to the child that there were no more cards to name and that the experimenter needed to clear the table for the next task (i.e., drawing a picture). Thus, children could carry out the prospective memory task of hiding the animal card without interrupting any ongoing activity.

It is important to point out that in order to investigate the effects of task interruption in relation to the model of Kvavilashvili and Ellis (1996), we used a procedure that is different from that employed in previous investigations. For example, in Zeigarnik's (1927) study, participants were interrupted by the experimenter halfway through the tasks (see also Mäntylä & Sgaramella, 1997). In the present study, there was no external agent interrupting an ongoing activity when children encountered a target picture of an animal. Instead, when this picture appeared in the middle of the stack, the children themselves had to interrupt their own ongoing activity. In other words, in the present study we investigated the effects of a need to interrupt a current activity, rather than the effects of an externally induced interruption, on prospective memory performance.

In Experiment 1 we tested 5- and 7-year-old children. This provided a starting point for our later studies by showing that the task was suitable for young children and revealing an interesting pattern of findings. In Experiment 2, an additional group of 4-year-old children and larger samples were involved to enhance the power and the possibility of obtaining a larger effect size for age. In Experiment 3, children's retrospective recall was also tested in order to investigate the relationship between prospective and retrospective memory recall. In addition, a possible confound in the task-interruption manipulation that existed in Experiments 1 and 2 was controlled for.

Our initial choice of age was dictated by the following considerations. First, research on children has produced mixed findings about whether there are age differences in prospective memory between 5 and 7 years of age. Meacham and Dumitru (1976) reported significant differences in performance of 5- and 7-year-old children, whereas no reliable differences were found between these ages in the study conducted by Meacham and Colombo (1980; see also Kurtz-Costes, Schneider, & Rupp, 1995). Second, significant developmental changes within this period have been amply documented in retrospective memory literature (see Flavell, Beach, & Chinsky, 1966; Gathercole, 1998; Kail, 1990). For example, in a study conducted by Kurtz-Costes et al. on 5- and 7-year-old children, highly significant effects of age were obtained in as many as seven different retrospective memory tasks. In contrast, no age effect was observed in a prospective memory task in which children had to remind the experimenter to do something at the end of the experimental session. If the present study were also to fail to establish an effect of age on children's prospective memory performance, then this finding, together with that of Kurtz-Costes et al., could be indicative of an interesting dissociation between the developmental patterns in prospective and retrospective memory.

Experiment 1

Method

Participants. Forty-eight pupils were recruited from a local primary school. Half of the children were 5 years old (mean age = 5 years 5 months), and half were 7 years old (mean age = 7 years 4 months). Each age group had equal numbers of boys and girls.

Design. The design was a 2 × 2 between-subjects factorial in which we varied the age of participants (5 years vs. 7 years) and task interruption (no interruption vs. interruption). There were 12 participants in each of the four experimental conditions.

Materials and procedure. Eighty line drawings of concrete nouns were prepared. They were glued to orange, square-shaped cards (12.5 cm × 12.5 cm). Half of the drawings were taken from Snodgrass and Vanderwart's (1980) standardized set of pictures; we prepared the other half. These 80 cards were divided into four stacks. In each stack there was one target card depicting an animal: a cow in Stack 1, a dog in Stack 2, a pig in Stack 3, and a horse in Stack 4. The presentation order of the four stacks and the cards within a stack was the same for all children. However, in the interruption condition, the target pictures were always placed as the 10th card in the stack, and in the no-interruption condition, as the 20th card in the stack (i.e., the last card in the stack).

Children were tested individually in a small room containing a table in the center, chairs, and a work surface. Children were asked to sit at the table next to the experimenter and were introduced to a toy mole named "Morris" (positioned in the center of the table), who allegedly liked to play with children very much. It was explained that moles cannot see very well in daylight. The experimenter went on to say that the four stacks of cards that lay on the table belonged to Morris and that he was very curious to know what pictures were on these cards. The children were then told that they would be helping Morris by looking at these pictures one by one and telling him as accurately as possible what the pictures were. Children were also told that Morris would be happy if they drew some pictures for him throughout the session. All children expressed willingness to draw. Thus, children had to draw a picture for Morris and then name the pictures in the first stack of cards. This procedure was repeated until all four stacks of cards were named and four pictures were drawn.

After conveying these general instructions, the experimenter introduced the prospective memory task by telling the children informally that Morris was very scared of other animals. Therefore, if they happened to see a picture of an animal while naming the cards, they were asked to stop what they were doing, take the card with the animal on it, and hide it in a box that was on the work surface 2 m behind the child.[1] The experimenter demonstrated this step to the child (on average, it took 5–6 s to complete this action). Finally, the experimenter also showed the child, by using a couple of cards from the first stack, how to name the cards. One card was to be turned over at a time; the child had to name the picture and then put the card face down next to the stack. This was to be repeated until the entire stack was finished.

The experimenter then asked the children if they had understood the instructions and helped them recount the tasks (including the prospective memory one). Once the experimenter was satisfied that the children were aware of what they were required to do, the experimental procedure began. First, each child was given a piece of plain A4-size paper, a pencil, and some felt pens and was asked to draw a picture of a snowman. In subsequent drawing tasks the child was asked to draw a tree, a house, and a sheep.[2] Each drawing generally took 2 min to complete, but if the child took far less time to complete the drawing, she or he was advised to add some minor details to the drawing. When the child completed this task, the drawing was placed next to the mole, and the child was given the first stack of cards; the experimenter asked the child to start naming the pictures by turning over the cards one by one. No mention of the prospective memory task was made at this point. For half the children in each age group, the target pictures always occurred in the middle of the stacks (the interruption condition), and for the other half, they always occurred as the last cards in the stacks (the no-interruption condition). To measure the time it took a child to name each of the stacks, the experimenter surreptitiously switched the stopwatch on as soon as the child turned over the first card in a stack and switched it off as soon as the child had named the last card in a stack.

At the end of the procedure all children were praised for their good work. After this, children who had hidden the card on at least one occasion were asked how they remembered to do this: Did they think about hiding the card (a) all the time while they were drawing the pictures and naming the cards, (b) once in a while, or (c) only when they saw the picture of an animal?

Those who forgot to hide the card on all four occasions were given successive questions or prompts (increasing in specificity) to find out whether their failure was due to their complete forgetting of the instructions (i.e., a retrospective memory loss) or simply to their not carrying out the task at an appropriate moment. If, at the end of the experiment, children could not remember that the experimenter had previously asked them to hide the animal cards, then their failure could not be considered a prospective memory failure (cf. Einstein & McDaniel, 1990; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Maylor, 1993a). The first, most general prompt involved asking the children if, in addition to drawing the pictures and naming the cards, they were also supposed to do something else. If the children could not answer this question, a second, more specific question (intermediate prompt) involved asking them whether they were supposed to do something when they saw certain pictures on the cards. If the children were unable to answer this question as well, they were given the final, most specific prompt, which involved asking them what they had

[1] Two points need to be stressed in relation to prospective memory instructions. First, children could not see the box while sitting at the table unless they got up and turned around. In this way the box could not serve as an incidental cue reminding the children of the prospective memory task. Second, the prospective memory instructions did not allow a child to know exactly when the animal in the picture would appear (i.e., in the middle or at the end of the stack). In fact, the children did not even know whether the animal card would be in all or only some of the stacks.

[2] It slipped our attention when designing Experiment 1 that the last drawing that the child had to draw—the sheep—belonged to an animal category and could potentially serve as a prospective memory target. However, none of the children ever commented on this connection when asked to draw a picture of the sheep, nor did they act prospectively (i.e., hide the drawing) once the picture was completed.

to do when they saw the picture of an animal. Finally, children were thanked, praised again, and taken back to their classroom.

Results and Discussion

Children's performance on the picture-naming task was near perfect. On the majority of occasions the children produced a correct name. The experimenter also accepted understandable semantic and/or perceptual errors. If a child was unable to name a picture within 4 or 5 s, the experimenter told him or her the correct name, and the child then continued the task. It is important to note that all children, irrespective of their age, were able to correctly name the target pictures of animals.

Throughout the session children encountered the prospective memory target event (i.e., the picture of an animal) four times. As one can see from the upper panel of Table 1, 48% of children (eight 5- and fifteen 7-year-olds) remembered and 35% (ten 5- and seven 7-year-olds) forgot to hide the target card on all four occasions. The remaining 17% (six 5- and two 7-year-olds) remembered on only some (i.e., one, two or three) occasions.[3] The number of times (out of a possible four) the children remembered to hide the target picture was used as their prospective memory score. The mean scores as a function of age and task interruption are presented in Table 2.

The prospective memory scores were entered into a 2 (age) × 2 (task interruption) between-subjects analysis of variance (ANOVA). This analysis revealed a main effect of age, $F(1, 44) = 5.07$, $p < .05$, indicating that 7-year-olds tended to have better prospective memory scores ($M = 2.7$) than 5-year-olds ($M = 1.7$). Furthermore, there was a highly significant effect of task interruption, $F(1, 44) = 13.65$, $p < .005$. In the no-interruption condition, children's prospective memory scores were reliably higher ($M = 3.0$) than in the interruption condition ($M = 1.4$). The interaction between the independent variables was not significant, $F(1, 44) = 1.37$, $p > .05$. It is interesting, however, that although task interruption explained a considerable amount of variability in performance (partial $\eta^2 = .24$) and had sufficient power (.95), the effect size for age was considerably smaller (partial $\eta^2 = .10$) and had insufficient power (.59).

The questioning of children at the end of the experiment yielded the following data. First, postexperimental probing of those 17 children (ten 5- and seven 7-year-olds) who forgot to hide the cards on all four occasions revealed that all were able to say what they were supposed to do when they saw a picture of an animal.[4] Second, the majority of those 31 children (74%) who remembered to carry out an intended action at least once throughout the session reported that they remembered about the prospective memory task only when they encountered the target cards. Only 8 children (26%) said they thought about this task all the time. As one can see from Table 3, there were no age differences among the children in this respect, $\chi^2(1, N = 31) = 0.009$, $p > .05$.

The main finding that emerged from Experiment 1 is that those children who were engaged in the card-naming task (the interruption condition) were less likely to remember the prospective memory task than those who had just finished this task (the no-interruption condition). In other words, those who had to interrupt their ongoing picture-naming activity in order to hide the animal cards displayed higher levels of forgetting than those who did not

Table 1
Number of Children in Experiments 1, 2, and 3 Who Remembered to Perform a Prospective Memory Task on All Four Occasions, on None of the Occasions, or on Only Some (One, Two, or Three) Occasions as a Function of Age and Task Interruption

	Interruption				No interruption			
Age (in years)	All	None	Some	Total	All	None	Some	Total
Experiment 1								
5	1	9	2	12	7	1	4	12
7	5	5	2	12	10	2	0	12
Total	6	14	4	24	17	3	4	24
Experiment 2								
4	3	11	6	20	12	7	1	20
5	5	11	4	20	15	4	1	20
7	11	8	1	20	19	1	0	20
Total	19	30	11	60	46	12	2	60
Experiment 3								
4	3	12	1	16	10	6	0	16
5	7	6	3	16	10	5	1	16
7	6	6	4	16	14	2	0	16
Total	16	24	8	48	34	13	1	48

Table 2
Mean Number of Successful Prospective Memory Responses as a Function of Age and Task Interruption in Experiments 1, 2, and 3

	Interruption		No interruption	
Experiment and age	*M*	*SD*	*M*	*SD*
Experiment 1				
5 years	0.58	1.24	2.83	1.59
7 years	2.17	1.95	3.33	1.56
Experiment 2				
4 years	1.25	1.62	2.55	1.93
5 years	1.35	1.75	3.10	1.65
7 years	2.30	1.98	3.80	0.89
Experiment 3				
4 years	0.94	1.69	2.50	2.00
5 years	2.06	1.91	2.68	1.89
7 years	2.25	1.84	3.50	1.36

[3] It should be pointed out that these percentages are very similar to the ones reported in several studies on adults in which the majority of participants also remembered or forgot the prospective memory task on all target occasions (e.g., see Einstein & McDaniel, 1990; McDaniel & Einstein, 1993).

[4] Unfortunately, due to experimenter error, the data about the type of prompt (general vs. intermediate vs. specific) that made the children recall retrospectively the prospective memory instructions were missing. Therefore we could not make age comparisons in this respect (however, see the *Results* section of Experiments 2 and 3).

Table 3
Number of Children (Remembering Prospective Memory Task on at Least One or More Occasions) in Experiments 1, 2, and 3 Who Reported Either Having Remembered the Intention Only When Seeing the Target Picture or Having Thought About It All the Time

Experiment and age	Self-reports: Remembered only when seeing card	Self-reports: Thought about task all the time	Total
Experiment 1			
5 years	11	3	14
7 years	12	5	17
Total	23	8	31
Experiment 2			
4 years	7	2	9[a]
5 years	17	8	25
7 years	16	15	31
Total	40	25	65
Experiment 3			
4 years	8	2	10
5 years	10	8	18
7 years	16	7	23
Total	34	17	51

[a] Due to experimenter error, the data of thirteen 4-year-olds were missing.

have to interrupt this activity. There was also a main effect of age. On the whole, 7-year-olds were better at remembering a prospective memory task than 5-year-olds. However, the size of this effect was relatively small, and it did not have an acceptable level of power. Finally, the lack of interaction between the independent variables indicates that task interruption posed similar difficulties for both age groups.

Experiment 2

Given the findings from Experiment 1, we wished to use a different set of materials to confirm the effects of task interruption. Second, we wished to determine whether increasing the age range would continue to produce an effect of task interruption and increase the effect of age on prospective memory scores. Consequently, Experiment 2 was conducted with a different (and improved) set of materials and instructions, and a group of 4-year-olds was included. The number of participants per cell was increased from 12 to 20.

Method

Participants. A total of 120 children were tested. Eighty pupils from two primary schools were recruited. Half of the children were 5 years old (mean age = 5 years 5 months) and half were 7 years old (mean age = 7 years 5 months). Forty children aged 4 years (mean age = 4 years 5 months) were recruited from two nursery schools. Children were tested individually in a quiet room provided by the schools.

Design. The design was a 3 × 2 between-subjects factorial in which we varied the age of participants (4 years vs. 5 years vs. 7 years) and task interruption (no interruption vs. interruption). There were 20 children in each of the six experimental conditions.

Materials and procedure. Eighty line drawings of concrete nouns were prepared. This time all the drawings were taken from Snodgrass and Vanderwart's (1980) standardized set of pictures and were glued to standard-sized (15 cm × 10 cm) white index cards. The 80 drawings represented 20 categories (e.g., furniture, plants, clothing, fruits, etc.), with four examples from each category. Thus, the four stacks of 20 cards were matched for meaning and familiarity. The mean familiarity ratings of the pictures in Stack 1, Stack 2, Stack 3 and Stack 4, calculated from the normative data provided by Snodgrass and Vanderwart, who used a 5-point rating scale, were 3.77, 3.77, 3.67 and 3.60, respectively ($F < 1$).[5] In addition, different animal pictures were used as the target cards: a deer in Stack 1, a fox in Stack 2, a rhino in Stack 3, and a bear in Stack 4. As in Experiment 1, the target pictures always occurred as the 10th card in the stack in the interruption condition and as the 20th (i.e., the last) card in the no-interruption condition. Finally, an additional set of 10 practice cards was also prepared.

The procedure of Experiment 2 was similar to that of Experiment 1 except for some minor modifications. For example, children were told that it was the mole's birthday on that day and that Morris received the four stacks of cards from his friends as a birthday present; the child was asked to draw four pictures for the mole as a present for his birthday. Initially, the children were asked to draw a picture of a boat. In subsequent drawing tasks they were asked to draw a birthday cake, a clown, and a castle. Furthermore, rather than showing the children how to name the cards with two or three cards from the first stack of cards, the experimenter asked the children to practice first with the practice stack of 10 cards. There were no animal pictures in this practice stack.

Results and Discussion

As in Experiment 1, children encountered the target pictures of an animal four times while being engaged in naming the cards. As one can see from the middle panel of Table 1, 53% of children remembered (fifteen 4-, twenty 5-, and thirty 7-year-olds) and 36% forgot (eighteen 4-, fifteen 5-, and nine 7-year-olds) to hide the animal card on all four occasions. The remaining 11% (seven 4-, five 5-, and one 7-year-old) remembered on only one, two, or three occasions, respectively.

The dependent variable was again the number of times (out of a possible four) the children remembered to hide the target cards, which always occurred either at the end of the stacks (the no-interruption condition) or in the middle (the interruption condition). Children's prospective memory scores (for means see Table 2) were then entered into a 3 (age) × 2 (task interruption) between-subjects ANOVA.

This analysis revealed a main effect of age, $F(2, 114) = 5.00$, $p < .01$. The mean scores for 4-, 5-, and 7-year-olds were 1.90, 2.20, and 3.05, respectively. Planned comparisons showed that reliable differences existed only between 4- and 7-year-olds, $t(79) = -3.07$, $p < .005$, and 5- and 7-year-olds, $t(79) = -2.22$, $p < .05$, whereas the difference between 4- and 5-year-olds was not statistically reliable ($p > .05$; all tests were two-tailed). Although the effect of age was statistically significant, it is important to note that, as in Experiment 1, the effect size was again relatively small (partial $\eta^2 = .08$). This time, however, due

[5] After we conducted Experiment 2, Cycowicz, Friedman, and Rothstein (1997) published normative data for Snodgrass and Vanderwart's (1980) pool of pictures for 5–7-year-old children. The mean familiarity ratings of the pictures in four stacks of cards based on the normative data for children were 2.91, 2.79, 2.77, and 2.76 for Stack 1, Stack 2, Stack 3, and Stack 4, respectively ($F < 1$). The lower familiarity ratings on the normative data for children reflect that "young children show a smaller range and less variation in their ratings of familiarity" (Cycowicz et al., 1997, p. 182).

to the enhanced number of participants, we had a sufficient level of power (.80).

The effect of task interruption was again highly significant, $F(1, 114) = 27.34$, $p < .001$. On average, children's prospective memory performance was reliably better in the no-interruption condition ($M = 3.15$) than in the interruption condition ($M = 1.63$). As in Experiment 1, this effect had a high level of power (.99) and explained 18% of the variability in performance. Finally, there was no interaction between the independent variables ($F < 1$).

It could be argued that the superior performance of children in the no-interruption condition was because they had developed an expectation that the animal card would be the last one in a stack. Such an expectation, or "priming," would be less likely in the interruption condition given the difficulties in keeping track of the exact (i.e., the 10th) position of the target card in the stack.

Given this argument, it is therefore interesting to see whether the effect of interruption is present for the very first prospective memory target, as no expectation could have been developed while children were naming the first stack of cards. The number of children who remembered or forgot to hide the first prospective memory target picture in the interruption and no-interruption conditions (collapsed across the age variable) is presented in Table 4. As one can see from this table, the effect of task interruption is still highly significant, $\chi^2(1, N = 120) = 22.94$, $p < .00001$. The same results were obtained when similar analyses were conducted on each age group separately (all $ps < .01$).

The postexperimental probing of those 42 children (eighteen 4-, fifteen 5-, and nine 7-year-olds) who forgot their intention on all four occasions indicated that the retrospective knowledge of what they were supposed to do when they saw the picture of an animal was preserved at the end of the session; they just failed to remember to perform the task in response to the target cards. It is also interesting that although 56% of the 7-year-olds were able to recount the prospective memory instructions on the very first prompt (the least specific one), the majority of the 4- and 5-year-olds (72% and 67%, respectively) were able to do so only on the second or the third (most specific) prompt. This difference, however, did not achieve statistical significance, $\chi^2(2, N = 42) = 3.48$, $p = .17$ (see Table 5 for the raw data).

In line with the results of Experiment 1, the majority (62%) of the children (twenty-two 4-, twenty-five 5-, and thirty-one 7-year-olds) who remembered to carry out an intended action at least once throughout the session reported that they remembered about the prospective memory task only when they encountered the target cards. Thirty-eight percent said they thought about the task all the time. As one can see from Table 3, there were no age differences among the children in this respect, $\chi^2(2, N = 65) = 2.73$, $p > .05$.

Table 4
Number of Children in the Interruption and the No-Interruption Conditions in Experiments 2 and 3 (Collapsed Across Age Variable) Who Remembered or Forgot to Hide a Target Picture in Stack 1

Experiment and condition	Prospective memory performance on first target: Remembered to hide	Forgot to hide	Total
Experiment 2			
Interruption	21	39	60
No interruption	47	13	60
Total	68	52	120
Experiment 3			
Interruption	23	25	48
No interruption	35	13	48
Total	58	38	96

Table 5
Number of 4-, 5-, and 7-Year-Old Children in Experiments 2 and 3 Who Forgot to Hide Target Cards on All Four Occasions But Retrieved Prospective Memory Task at End of Experiment Either on First Prompt or on Subsequent More Specific Prompts

Experiment and age	Prompts: First	Second and third	Total
Experiment 2			
4 years	5	13	18
5 years	5	10	15
7 years	5	4	9
Total	15	27	42
Experiment 3			
4 years	0	16	16
5 years	0	9	9
7 years	4	4	8
Total	4	29	33

In conclusion, although Experiment 2 had different materials and increased power, it produced results that were similar to those of Experiment 1. Thus, there was a significant effect of task interruption, and the analysis of the first stack suggests that this effect was unlikely due to expectation or "priming" in the no-interruption condition. On the other hand, despite an increased power and the inclusion of a group of 4-year-old children, the effect of age was again relatively small, and it explained even less variability (8%) than in Experiment 1. This result seems to be in a sharp contrast to the large differences in children's retrospective memory that are well documented in the literature for children between the ages of 4 and 7 (e.g., Appel et al., 1972; Baker-Ward, Ornstein, & Holden, 1984; Gathercole, 1998; Sodian, Schneider, & Perlmutter, 1986).

Experiment 3

The principal aim of Experiment 3 was to compare the developmental trajectory of prospective and retrospective memory and to investigate a relationship, if any, between them. Children's retrospective memory was tested by giving them a surprise recall test immediately after they had finished naming a fourth stack of cards that was used to assess prospective memory. In particular, they were asked to tell the experimenter what pictures they had seen in the last stack of cards. An incidental recall test was chosen because Maylor (1993a) reported a small but significant correlation, $r(84) = .25$, $p < .05$, between the prospective memory successes and an incidental retrospective task in elderly participants.

Experiment 3 also provided an opportunity to answer a methodological question about the task-interruption manipulation. This involved the issue of the position of the prospective memory target in a stack of cards in the interruption/no-interruption conditions. In both Experiments 1 and 2, the target card of an animal always occurred in the 10th position in the interruption condition and in the 20th position in the no-interruption condition. Thus, it is possible that better prospective memory in the no-interruption condition was due to the fact that the animal card always occurred in the 20th position rather than in the 10th position.

In order to answer this question, we asked children in the interruption condition in Experiment 3 to name 20 cards in each stack; the animal card was in the 10th position (as in Experiment 2). In contrast, children in the no-interruption condition received only 10 cards in each stack, and the animal cards always occurred in the last (i.e., the 10th position). In this way, both the interruption and no-interruption conditions had the target card occurring in exactly the same position in a stack. In addition, the order of presenting the four stacks was counterbalanced so that each stack (and its target picture) occurred equally often as the first, second, third, and fourth stack.

Method

Participants. A total of 96 children were tested. Thirty-two 5-year-old (mean age = 5 years 5 months) and thirty-two 7-year-old (mean age = 7 years 4 months) children were recruited from a local primary school that had not previously participated in our study. Thirty-two 4-year-old children (mean age = 4 years 5 months) were recruited from a nursery-school class attached to the school. Children were again tested individually in a quiet room provided by the school.

Design. The design was a 3 × 2 between-subjects factorial in which we varied the age of participants (4 years vs. 5 years vs. 7 years) and task interruption (no-interruption vs. interruption). There were 16 children in each of the six experimental conditions.

Materials and procedure. The materials and procedure were the same as those used in Experiment 2 except for the changes described previously. Thus, the target pictures always occurred as the 10th card in the stack in both the interruption and the no-interruption conditions. In the interruption condition there were 20 cards in each stack, whereas in the no-interruption condition, only the first 10 cards of each 20-card stack were used. The presentation order of the cards within each stack was the same for all children in both conditions. However, the presentation order of the target pictures was counterbalanced, because each stack occurred equally often as the first, second, third, and fourth stack. Finally, when children finished naming the last stack of cards, they were asked to recall all the pictures from that stack. The experimenter recorded the proportion of correctly recalled items, the proportion of incorrectly recalled items (i.e., the items from the preceding stacks), and the number of confabulations (i.e., new items not seen in any of the four stacks of cards), if any.

This recall test was followed by the same postexperimental probing of those children who forgot to hide the card on all four occasions, as in Experiments 1 and 2. None of the children in Experiments 1 and 2 who remembered to hide the card on at least one occasion responded that he or she thought about the prospective memory task once in a while. Consequently, this option was dropped, and the order of presenting the remaining two questions (i.e., did you think about hiding a card all the time or only when you saw an animal card?) was counterbalanced to avoid the possibility that children were choosing only the last option (see Johnson & Harris, 1994, for children's tendency to choose a last option when presented with alternative choices).

Results and Discussion

The analyses conducted on children's prospective memory scores are reported first. This is followed by an analysis of the retrospective memory data. Finally we present the results from multiple regression analyses, which examined the relation between children's prospective and retrospective memory performance.

Prospective memory performance. The dependent variable was the number of times (out of a possible four) the children remembered to hide the target cards. These data (for means see Table 2) were entered into a 3 (age) × 2 (task interruption) between-subjects ANOVA. This revealed a main effect of age, $F(2, 90) = 3.34, p < .05$. The 7-year-olds had better prospective memory scores than the 5-year-olds, who, in turn, had better scores than the 4-year-olds (Ms = 2.87, 2.37, and 1.72, respectively). Planned comparisons of the means showed that reliable differences existed only between 4- and 7-year-olds, $t(63) = -2.57, p < .02$, whereas the difference between 4- and 5-year-olds and 5- and 7-year-olds were not statistically significant (both ps > .05; all tests were two-tailed).

There was also a main effect of task interruption, $F(1, 90) = 9.77, p < .005$, so that children's prospective memory performance was better in the no-interruption condition ($M = 2.90$) than in the interruption condition ($M = 1.75$). There was no interaction between the independent variables ($F < 1$). It is interesting that the effect size for age was similar to those obtained in previous experiments (partial $\eta^2 = .07$). However, the effect size for task interruption was not as large as before (partial $\eta^2 = .10$).

Another finding that was replicated from Experiment 2 was that the effect of task interruption was present on the very first target picture, $\chi^2(1, N = 96) = 3.86, p < .02$, indicating that this effect was not due to an expectation that the picture of an animal would be the last one in a stack (for raw data see Table 4). Furthermore, the postexperimental probing of those 38 children (eighteen 4-, twelve 5-, and eight 7-year-olds) who forgot to hide the target card on all four occasion showed that 87% could remember the prospective memory task when prompted. There were only 5 children (two 4- and three 5-year-olds) who could not recount the task even after the third most specific prompt. However, after the experimenter described a task to them, they were all able to recognize the task by admitting that it had been given to them but that they had completely forgotten about it. It is worth noting that when the data of these 5 children were excluded from the ANOVAs reported previously, the same pattern of results was obtained. Finally, although 50% of 7-year-olds were able to recount the task on the very first prompt, all the 4- and 5-year-old children could do so on only the subsequent (more specific) prompts (see Table 5).

When those 58 children who remembered to hide the target card on at least one occasion were asked after the experiment whether they remembered about the prospective memory task only when they encountered the animal card or whether they were thinking about this all the time, 7 children (four 4-, two 5-, and one 7-year-old) said that they did not know. This type of response, which was not present in Experiments 1 and 2, could be due to the fact that in the present experiment, there was a short delay between finishing the last stack of cards and beginning the probing. The majority of remaining children (67%) indicated that they remembered about the prospective memory task only when they saw the animal picture. Although more 5- and 7-year-olds than 4-year-olds tended to report that they were thinking about hiding the target card all the time (see Table 3), this difference was not statistically significant, $\chi^2(2, N = 51) = 1.89, p > .05$.

Retrospective memory performance. The mean proportion of intrusions (i.e., the number of items recalled from the first three stacks divided by the total number of items in those stacks) and the mean number of confabulations were so small (less than 1% and less than 1, respectively) that they could not be subjected to an ANOVA. Despite such low numbers of intrusions and confabulations, the proportion of correctly recalled items from Stack 4 was far from perfect, most probably due to the incidental nature of the recall task (see Table 6 for means).

In order to determine if there were developmental changes in children's incidental retrospective recall, we entered a proportion of correctly recalled items into a 3 (age) × 2 (task interruption) between-subjects ANOVA as a dependent variable. This analysis revealed a main effect of age, $F(2, 90) = 7.67, p < .005$. Planned comparisons of the mean proportions of correctly recalled pictures ($M_1 = .13$, $M_2 = .15$, and $M_3 = .24$ for 4-, 5-, and 7-year-old children, respectively) showed that there was no difference between the recall of 4- and 5-year-old children, $t(63) = 0.69, p > .05$, but there was a highly significant difference between 5- and 7-year-olds, $t(63) = -2.99, p < .005$, and 4- and 7-year-olds, $t(63) = -3.68, p < .001$ (all tests were two-tailed).

There was also a main effect of task interruption, $F(1, 90) = 19.78, p < .001$, so that children in the no-interruption condition had reliably better recall scores ($M = .23$) than in the interruption condition ($M = .12$). This finding was not surprising given that the former had to recall a list of only 10 items, whereas the latter had to recall a 20-item list. In the memory literature, a decreased probability of recalling an item as the number of items in the list increases is called a *list-length effect* (Ohrt & Gronlund, 1999; Strong, 1912). Therefore, it should be obvious that in the case of incidental retrospective recall, the effect of task interruption was actually tantamount to the list-length effect. In other words, what counted as a task-interruption variable for the prospective memory task was actually a list-length variable for the retrospective memory task. Finally, there was no interaction between the independent variables ($F < 1$), indicating that the effect of age was significant in both 10- and 20-item conditions.

The effect size was .15 for age and .18 for list-length. Both effects had a high level of power (.94 and .99, respectively). If children were warned about the recall test before the beginning of the fourth stack, the effect size for age could have been even larger because the older children would have used more efficient strategies (e.g., Flavell et al., 1966; Gathercole, 1998). Nevertheless, it is interesting to note that age explained twice as much variability in children's retrospective recall (15%) than in their prospective memory scores (7%).[6]

Table 6
Mean Proportions of Correctly Recalled Items From Last Stack of Cards (Retrospective Memory Test) as a Function of Age and Task Interruption in Experiment 3

	Interruption		No interruption	
Age (in years)	*M*	*SD*	*M*	*SD*
4	.07	.06	.19	.12
5	.11	.08	.19	.15
7	.17	.11	.31	.15

The relationship between prospective and retrospective memory. In order to examine the relationship between prospective and retrospective memory scores, we conducted a multiple regression analysis on prospective memory scores, with the retrospective memory scores, age in months, and task interruption (as a dichotomous variable) as predictors. We chose this form of analysis because both prospective and retrospective memory scores were affected by such variables as age and task interruption, and these influences could affect the detection of the relationship between the two memory scores. All predictor variables were entered simultaneously. The standardized beta coefficients and the percentage of explained variance are listed in Table 7. As one can see from this table, the only significant predictor of prospective memory performance, when all other variables were controlled for, was task interruption. It is interesting that a different pattern of results emerged when a similar multiple regression analysis was conducted on retrospective memory scores. As one can see from Table 7, in addition to task interruption, children's age in months was also a significant predictor of retrospective scores when all the other variables were controlled.

In conclusion, the results of Experiment 3 replicated the findings of Experiments 1 and 2 with respect to the effects of age and task interruption on children's prospective memory performance. In addition, there were different profiles of results for children's retrospective and prospective memory scores. Finally, the results of the multiple regression analyses indicated that children's performance on prospective and retrospective tasks was unrelated when effects of other variables (i.e., age and task interruption) were controlled.

General Discussion

The aim of the present experiments was to explore the effects of age and task interruption on event-based prospective memory. An additional issue concerned the relationship between children's prospective and retrospective memory performance. By meeting these objectives, we hoped to begin to remedy the existing gap in the literature on developmental aspects of prospective memory; this gap is particularly surprising given the acknowledged importance of prospective memory in helping children to cope with various everyday tasks, such as, for example, carrying out family chores.

A major finding concerns the effects of age on prospective memory. There is ample evidence in the literature that, over the age range that was studied in the present experiments (4–7 years), children's performance in explicit retrospective memory tasks shows an appreciable improvement, and this has been attributed to changes in children's storage and processing functions (see Gathercole, 1998). In contrast, our findings indicate that although 7-year-olds performed better on prospective memory tasks than 4- and 5-year-olds, the effects of age were not large. Thus, in all three experiments, age explained only 7–10% of the variability in pro-

[6] However, this comparison should be taken with caution, because prospective and retrospective memory scores were based on a different number of data points (i.e., 4 in the former and 10 or 20 in the latter).

Table 7
Standardized Beta Coefficients for Regression Analyses Predicting Prospective Memory and Retrospective Memory Scores in Experiment 3

Predictor variable	Criterion variable: Prospective memory	Criterion variable: Retrospective memory
Age	.17	.33**
Task interruption	.22*	.34**
Retrospective memory	.18	—
Prospective memory	—	.15
R^2	.14	.28

Note. Each column represents a separate multiple regression analysis.
* $p < .05$. ** $p < .001$.

spective memory. Furthermore, the regression analyses conducted in Experiment 3 showed that children's age was not a significant predictor of prospective memory performance when the effects of other variables (such as task interruption and retrospective memory recall) were controlled.

These results are largely consistent with earlier findings from laboratory and naturalistic studies that failed to detect reliable age differences between 5- and 7-year-olds (Kurtz-Costes et al., 1995; Meacham & Colombo, 1980) and between 2-, 3-, and 4-year-olds (Somerville et al., 1983). They also can be seen as providing support for Winograd's (1988) claim that, in comparison to retrospective memory, prospective memory skills develop at a relatively early age. Indeed, in a pilot study we were surprised at young children's high level of performance and had to introduce several modifications into our basic procedure in order to eliminate the ceiling effects in 5- and 7-year-old children.

It is important to note that even with these modifications, the majority of 7-year-olds in the no-interruption condition still remembered to hide the card on all four occasions (i.e., performed at ceiling), especially in Experiments 2 and 3 (see Table 1). Therefore one could argue that the effects of age obtained in the present study were masked or substantially reduced.[7] If this were the case then one would expect to obtain much larger effects of age in the interruption condition, in which there was room for substantial improvement among older children due to the absence of any ceiling effects. However, one-way ANOVAs with age group as a between-subjects variable conducted separately on the interruption and no-interruption conditions showed that the amount of variability in prospective memory explained by age in both conditions was still relatively small and of comparable magnitude (7% and 10% in Experiment 2 and 10% and 6% in Experiment 3 for the interruption and the no-interruption conditions, respectively). Moreover, none of the age effects obtained separately for these conditions reached the conventionally accepted level of statistical significance (i.e., $p < .05$). The difference in effect sizes was much larger in Experiment 1 (20% and 3% in the interruption and no-interruption conditions, respectively) but, as indicated earlier, this experiment lacked sufficient power due to the small number of participants. On the whole, this pattern of results does not seem to support the idea that an age effect was masked by older children's performing at ceiling in the no-interruption condition.

In summary, the findings reported in previous studies and our own indicate that the developmental changes in prospective memory in early childhood are modest and sometimes difficult to identify. It is intriguing that similar findings have been obtained in research on the elderly. For example, in her review of the literature on aging and prospective memory, Maylor (1993b) concluded that "prospective memory is much less impaired by age than retrospective memory" (p. 547; see also Rendell & Thompson, 1999).

Of course, developmental changes in prospective memory might occur when a larger age range or a different type of prospective memory task is used. It should be remembered that Kurtz-Costes et al. (1995) found that there was no difference in performance of 5- and 7-year-old children, but there was a significant difference between the latter and 9-year-olds. Similarly, Kerns (2000), who recently developed an ingenious task for studying time-based prospective memory in children (requiring more self-initiating and monitoring), found a reliable (albeit modest) effect of age in a sample of 7–12-year-old children. It is obvious that in the future, research on children's prospective memory should concentrate on wider age ranges and different types of tasks in order to determine the long-term developmental trajectory of prospective memory.

A second important finding from our set of experiments involved the effects of task interruption on prospective memory. Although a need to interrupt an ongoing task in order to carry out an intended action has generally been accepted to be a defining feature of many everyday prospective memory tasks, this important dimension (i.e., interruption vs. no interruption) has never been directly subjected to investigation.

Preliminary data relevant to this issue have recently been obtained by Cockburn (1995, 1996) from a clinical adult population. In her studies, patients had to remember to terminate an ongoing task after exactly 5 min. Cockburn concluded that "if there is a hierarchy of levels of self-initiation, tasks that require interruption of an ongoing action may represent the most demanding level" (1995, p. 95). Unfortunately, it is not clear from Cockburn's studies whether her patients failed to remember their intention (to terminate the ongoing activity) when 5 min elapsed or whether they remembered in time but could not resist an urge to finish the task at hand (see, e.g., Ovsiankina, 1928, cited in Lewin, 1926/1951). In the present study, we therefore were careful to ensure that it was necessary to interrupt the ongoing activity in order to carry out a prospective memory task, and this was not confounded with the need to terminate this activity prior to its natural conclusion. Thus, children in the interruption condition could resume their ongoing picture-naming task immediately after they had hidden the target picture.

The analyses of data obtained in all three of the experiments confirmed our hypothesis about the effects of task interruption on prospective memory. Task interruption consistently explained a significant amount of variance in prospective memory (particularly in Experiments 1 and 2) and had high levels of power. However, given a lack of previous research on this topic, this finding needs to be treated with some caution. It is possible that smaller effect sizes may be obtained with different age ranges, prospective mem-

[7] We are grateful to an anonymous reviewer for pointing out this possibility to us.

ory tasks, and/or materials.[8] Obviously, future studies are needed to confirm the robustness of this finding.

At this stage one can only speculate about the reasons for the strong effect of interruption obtained in the present study. One explanation is related to the procedures that were used. Although all prospective memory tasks studied in a laboratory necessitate an interruption of an ongoing activity, this interruption is usually very short lived (e.g., pressing a key, circling a target word, etc.). In the present study, children in the interruption condition had to stop the picture-naming task for about 5–6 s in order to hide the target card. Consequently, it may be that because we used procedures with a marked disengagement from the ongoing activity, this resulted in a large difference between the interruption and no-interruption conditions.

Another way of accounting for the effect of interruption is to assume that when the children were naming the cards, most of their attentional resources were taken up by this task, and they were less likely to remember to hide a target card with an animal on it (despite that they could clearly see the animal and, in addition, had to name it aloud). When, however, the animal card occurred as the last one in the stack, the children named it, and because they were not engaged in any other activity for the following few seconds, more resources may have been available to recognize the animal card as the target for the requested action (cf. Einstein & McDaniel, 1996; Ellis & Milne, 1996). Therefore, one could argue that the effect of interruption would be attenuated if one used an ongoing task that required minimal attentional resources from children.

A final set of findings obtained in the present study concerns the relation between prospective and retrospective memory. This topic is undoubtedly an important one, but so far only limited advances in understanding have been made. A number of studies have, by and large, failed to establish reliable correlations between prospective and retrospective memory in adults (e.g., Einstein & McDaniel, 1990; Kidder, Park, Hertzog, & Morrell, 1997; Kvavilashvili, 1987; Maylor, 1990; Meacham & Leiman, 1982). It has also been argued that because retrospective memory tasks themselves do not necessarily correlate with each other (e.g., Underwood, Boruch, & Malmi, 1978), it is more fruitful to investigate whether certain variables exert similar influences on both types of memory (e.g., McDaniel, 1995; McDaniel & Einstein, 1993). A recent and promising line of research in this respect involves neuropsychological inquiries into the existence of single and/or double dissociations between prospective and retrospective memory (Bisiacchi, 1996; Burgess & Shallice, 1997) and the involvement of different or similar brain regions in these two types of tasks (Glisky, 1996; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999).

It is interesting that in Experiment 3, different patterns of results emerged for children's prospective and retrospective memory scores. In the ANOVAs the effect of age explained twice as much variance in retrospective than in prospective memory scores. Moreover, in the regression analyses on prospective memory scores, the effect of age was not significant when all the other predictor variables were controlled for, whereas in the similar analysis on retrospective memory scores, age was a significant predictor. Finally, the results of the regression analyses also showed that there was no relationship between children's prospective and retrospective memory scores. These findings are indicative of a difference in the development of prospective and retrospective memory. They also support the idea that although prospective and retrospective memory may involve similar components of the memory system, the demands placed on these components may be very different (e.g., Kvavilashvili, 1987; Maylor, 1990; but see Roediger, 1996, and Hunt & Smith, 1996, for an opposing viewpoint).

Having discussed three major findings obtained in the present study, we now may ask how they inform the current theoretical models of prospective memory before we move to discussing their practical and methodological implications. A major question about prospective memory concerns whether it is predominantly an automatic process or requires a certain amount of controlled attentional resources. If our line of reasoning about the involvement of attentional resources in the task-interruption effect is correct, then one could argue that present findings provide some support for a *noticing + search* model proposed by Einstein and McDaniel (1996).

According to this model, prospective remembering involves a two-stage process in which encountering a target event will automatically elicit a feeling of familiarity (i.e., noticing), followed by a controlled search for an intended action. Although, at an intuitive level, prospective remembering seems to be an automatic process, as intentions are often reported to simply "pop into one's mind," the existence of a controlled stage in this process can be inferred from recent experiments using dual-task paradigms in which prospective memory was found to be significantly impaired if an ongoing task was attentionally demanding (see Einstein, Smith, McDaniel, & Shaw, 1997; Marsh & Hicks, 1998; for neuropsychological evidence see McDaniel et al., 1999). In the present study, it seems likely that the controlled search component of the noticing + search process would be more problematic for children in the interruption condition, given the concurrent demands of picture naming.

On the other hand, it is often supposed that automatic cognitive processes are relatively unaffected by developmental change (see Hasher & Zacks, 1979). Therefore, the small age effects obtained in the present study seem to be congruent with models that stress the automatic nature of retrieval in prospective memory tasks. Indeed, according to simple activation models (Einstein & McDaniel, 1996; Ellis, 1996; Goschke & Kuhl, 1996; Mäntylä, 1996), when a person encounters a prospective memory target, the latter enhances the levels of activation of intention representations, which results in automatic retrieval of a prospective memory task.

Thus, the findings of the present study concerning the effects of age and task interruption support two different accounts of prospective memory. It is interesting, however, that McDaniel, Robinson-Riegler, and Einstein (1998) have recently proposed a more detailed version of an activation model that tries to reconcile the automatic nature of prospective memory retrieval with the prospective memory impairment under divided attention conditions (see also McDaniel & Einstein, 2000). Their ideas are based on a systems view of memory (see Moscovitch, 1994) and assume

[8] It should be noted that the smaller effect size was obtained in the present study (in Experiment 3) even when we controlled for the confounding variable.

that prospective memory is mediated by a reflexive associative memory system subserved mainly by the hippocampus.

McDaniel et al. (1998) stressed the importance of automatic associative links between a prospective memory cue event and an intended action. Because their model rejects the necessity of a second controlled stage in prospective memory retrieval, they proposed the following two possibilities to explain the effects of divided attention on prospective memory. First, McDaniel et al. (1998) suggested that under divided attention conditions, it is unlikely that a cue event will receive sufficient attention to enable the automatic link to occur between the cue and a relevant memory trace (i.e., an intended action; for a similar suggestion, see Marsh & Hicks, 1998). Second, they supposed that even when an intended action is automatically retrieved, it may be immediately forgotten in the face of competing demands imposed by divided attention.

If the latter suggestion is correct, then the results of the present study could be accommodated by McDaniel et al.'s (1998) model. Thus, the idea that the retrieval of intention is largely an automatic process is consistent with the small age effects observed in our study. In addition, the idea that automatically retrieved intentions can easily be forgotten in the face of competing demands of an ongoing activity (or activities) is consistent with the finding that prospective memory performance was worse in the interruption than in the no-interruption condition. It is obvious, however, that in the future, more research needs to be carried out both on adults and children to explore the mechanisms that underlie the effects of divided attention and task interruption on prospective memory. Such studies will undoubtedly enable the further development and refining of current models of prospective memory.

Practical Implications

The results of the present study provide some simple guidelines to parents and teachers about the ways to enhance success in prospective memory tasks. Because children's prospective memory has been shown to be significantly influenced by task interruption, it is desirable that caregivers try to ensure that children will not be engaged in an activity when the prospective memory task should be carried out. This could be achieved by deliberately assigning children to the so-called activity-based tasks, which require them to do something only before the onset of or after finishing a certain prespecified activity (see Kvavilashvili & Ellis, 1996). A further possibility, based on previous investigation of the benefits of external cuing in children's prospective memory performance (Meacham & Colombo, 1980), is that a combination of an activity-based task with external cuing could be most beneficial in ensuring that children carry out their intentions on time (e.g., a toothbrush could be placed on the child's pillow to remind the child to brush his or her teeth before going to bed).

Methodological Implications

The present study has shown that prospective memory can be investigated in controlled situations with a simple and engaging task in children as young as 4 years of age (cf. Guajardo & Best, 2000). This can be considered an improvement over the single-intention paradigm (see Kvavilashvili, 1992) used by Meacham and his colleagues (Meacham & Colombo, 1980; Meacham & Dumitru, 1976) in which only a single yes–no response was obtained because there was only one retrieval opportunity. Our paradigm permits the collection of several responses in a single session. Furthermore, the use of a standardized setting provides the control necessary to eliminate the influence of extraneous or confounding variables that may be present in other investigations (e.g., Somerville et al., 1983). In addition, because the ongoing task involves naming the pictures and not reading the words (see Passolunghi et al., 1995), there is also a potential for our method to be used in 2- or 3-year-old children.

We were also careful to ensure that prospective memory failures were not due to retrospective forgetting of the contents of the prospective memory task. Thus, the postexperimental probing of those children who forgot to hide a card on all four occasions revealed that they were aware that they had been requested to carry out the prospective memory task. However, the postexperimental questioning of those children who remembered to hide the target card on at least one occasion revealed that the majority of children (74% in Experiment 1 and 62% in Experiment 2) did not constantly think about the to-be-performed action throughout the experimental session. Similar reports have been obtained in studies with adults (see Kvavilashvili, 1998).

An important feature of prospective memory in everyday life is that once an intention is formed, it is no longer necessary to think about it obsessively. Instead, a person switches to another activity (cf. Meier & Graf, 2000). However, at an appropriate moment, the prospective memory task tends to spring to one's mind, often without any obvious external cue (see Freud, 1901/1966, for a detailed description of this phenomenon). It thus appears that the task used in the present study adequately captures the most important features of prospective remembering as revealed in everyday life and enables quantitative measures of prospective memory to be obtained within a single and relatively short experimental session.

One potential drawback of the present method is that children in all age groups had to name the same number of cards. Given that there was a highly significant age effect in the time spent on naming the cards, there is a danger that the background task was more demanding for the younger children.[9] In future research it is perhaps advisable to make adjustments in the number of to-be-named cards according to the age of the children so that children in all age groups spend approximately the same amount of time on naming a stack of cards (e.g., see Messer, Kvavilashvili, & Kyle, 1998). Special care should be also taken to make sure that remembering the contents of the to-be-performed action does not pose

[9] In Experiment 1 we entered the time (in seconds) spent on naming the stacks as the dependent variable in a 2 (age) × 2 (task interruption) × 4 (stacks) mixed ANOVA, with the repeated measures on the last factor. This analysis revealed a highly significant main effect of age, $F(1, 44) = 35.01$, $p < .0005$, indicating that, on average, 7-year-olds were quicker at naming the cards than 5-year-olds ($M_1 = 58.29$ and $M_2 = 76.42$, respectively). There was also a reliable effect of stacks, $F(3, 132) = 12.26$, $p < .0005$, so that, on average, children tended to spend significantly more time on naming the first stack ($M_1 = 75.08$) than on each of the subsequent stacks ($M_2 = 66.92$, $M_3 = 64.42$, and $M_4 = 63.00$ for the second, third, and fourth stack, respectively, all $ps < .0005$). There was no significant effect of task interruption, and there were no interactions between independent variables. The same pattern of results was obtained in Experiments 2 and 3.

any demands on children's retrospective memory. In the present series of experiments there was some indication that younger children who forgot on all four occasions required more prompting than 7-year-olds in order to recount the contents of the prospective memory task (see Table 5).

In conclusion, given the early stage of research on children's prospective memory abilities, the results of the present study are both interesting and encouraging. They show that research on young children's prospective memory performance is feasible and may produce data that can have important theoretical and practical implications for prospective memory research in general and memory development in particular.

References

Appel, L. F., Cooper, R. G., McCarrel, N., Sims-Knight, J., Yussen, S. R., & Flavell, J. H. (1972). The development of the distinction between perceiving and memorizing. *Child Development, 43*, 1365–1381.

Baker-Ward, L., Ornstein, P. A., & Holden, D. J. (1984). The expression of memorization in early childhood. *Journal of Experimental Child Psychology, 37*, 555–575.

Beal, C. R. (1988). The development of prospective memory skills. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues* (Vol. 1, pp. 366–370). Chichester, England: Wiley.

Bisiacchi, P. S. (1996). The neuropsychological approach in the study of prospective memory. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 297–317). Mahwah, NJ: Erlbaum.

Brandimonte, M., Einstein, G. O., & McDaniel, M. A. (Eds.). (1996). *Prospective memory: Theory and applications*. Mahwah, NJ: Erlbaum.

Burgess, P. W., & Shallice, T. (1997). The relationship between prospective and retrospective memory: Neuropsychological evidence. In M. A. Conway (Ed.), *Cognitive models of memory* (pp. 247–272). London: Psychology Press.

Ceci, S. J., Baker, J. G., & Bronfenbrenner, U. (1988). Prospective remembering and temporal calibration. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues* (Vol. 1, pp. 360–365). Chichester, England: Wiley.

Ceci, S. J., & Bronfenbrenner, U. (1985). "Don't forget to take the cupcakes out of the oven": Prospective memory, strategic time-monitoring, and context. *Child Development, 56*, 152–164.

Cockburn, J. (1995). Task interruption in prospective memory: A frontal lobe function? *Cortex, 31*, 87–97.

Cockburn, J. (1996). Failure of prospective memory after acquired brain damage: Preliminary investigation and suggestions for future directions. *Journal of Clinical and Experimental Neuropsychology, 2*, 304–309.

Crovitz, H. F., & Daniel, W. F. (1984). Measurements of everyday memory: Toward the prevention of forgetting. *Bulletin of the Psychonomic Society, 22*, 413–414.

Cycowicz, Y. M., Friedman, D., & Rothstein, M. (1997). Picture naming by young children: Norms for name agreement, familiarity and visual complexity. *Journal of Experimental Child Psychology, 65*, 171–237.

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 717–726.

Einstein, G. O., & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 115–141). Mahwah, NJ: Erlbaum.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 996–1007.

Einstein, G. O., Smith, R. E., McDaniel, M. A., & Shaw, P. (1997). Aging and prospective memory: The influence of increased task demands at encoding and retrieval. *Psychology and Aging, 12*, 479–488.

Ellis, J. A. (1996). Prospective memory or the realization of delayed intentions: A conceptual framework for research. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 1–22). Mahwah, NJ: Erlbaum.

Ellis, J. A., & Milne, A. (1996). Retrieval cue specificity and the realization of delayed intentions. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 49A*, 862–887.

Flavell, J. H., Beach, D. R., & Chinsky, J. M. (1966). Spontaneous verbal rehearsal in a memory task as a function of age. *Child Development, 37*, 283–299.

Freud, S. (1966). *The psychopathology of everyday life*. (A. Tyson, Trans.). London: Ernest Benn Limited. (Originally published 1901)

Gathercole, S. E. (1998). The development of memory. *Journal of Child Psychology and Psychiatry, 39*, 3–27.

Glisky, E. L. (1996). Prospective memory and frontal lobes. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 249–266). Mahwah, NJ: Erlbaum.

Goschke, T., & Kuhl, J. (1996). Remembering what to do: Explicit and implicit memory for intentions. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 53–92). Mahwah, NJ: Erlbaum.

Guajardo, N. R., & Best, D. L. (2000). Do preschoolers remember what to do? Incentive and external cues in prospective memory. *Cognitive Development, 15*, 75–97.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108*, 356–388.

Hunt, R. R., & Smith, R. E. (1996). Representations may be restrictive: Where is the feeling of prospective memory? In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 157–171). Mahwah, NJ: Erlbaum.

Huppert, F. A., & Beardsall, L. (1993). Prospective memory impairment as an early indicator of dementia. *Journal of Clinical and Experimental Neuropsychology, 15*, 805–821.

Johnson, C. N., & Harris, P. L. (1994). Magic: Special but not excluded. *British Journal of Developmental Psychology, 12*, 35–51.

Kail, R. (1990). *The development of memory in children* (3rd ed.). New York: Freeman.

Kerns, K. (2000). The CyberCruiser: An investigation of development of prospective memory in children. *Journal of the International Neuropsychological Society, 6*, 62–70.

Kidder, D. P., Park, D. C., Hertzog, C., & Morrell, R. (1997). Prospective memory and aging: The effects of working memory and prospective memory task load. *Aging, Neuropsychology, and Cognition, 4*, 93–112.

Kurtz-Costes, B., Schneider, W., & Rupp, S. (1995). Is there evidence for intraindividual consistency in performance across memory tasks? New evidence on an old question. In F. E. Weinert & W. Schneider (Eds.), *Memory performance and competencies: Issues in growth and development* (pp. 245–262). Mahwah, NJ: Erlbaum.

Kvavilashvili, L. (1987). Remembering intention as a distinct form of memory. *British Journal of Psychology, 78*, 507–518.

Kvavilashvili, L. (1992). Remembering intentions: A critical review of existing experimental paradigms. *Applied Cognitive Psychology, 6*, 507–524.

Kvavilashvili, L. (1998). Remembering intentions: Testing a new method of investigation. *Applied Cognitive Psychology*, 12, 533–554.

Kvavilashvili, L., & Ellis, J. A. (1996). Varieties of intention: Some distinctions and classifications. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 23–51). Mahwah, NJ: Erlbaum.

Kvavilashvili, L., & Ellis, J. A. (Eds.). (2000). New perspectives in prospective memory. [Special issue]. *Applied Cognitive Psychology, 14*(7).

Lewin, K. (1951). Intention, will, and need. In D. Rapaport (Ed.), *Organization and pathology of thought* (pp. 95–153). New York: Columbia University Press. (Originally published 1926)

Mäntylä, T. (1996). Activating actions and interrupting intentions: Mechanisms of retrieval sensitization in prospective memory. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 93–114). Mahwah, NJ: Erlbaum.

Mäntylä, T., & Sgaramella, T. (1997). Interrupting intentions: Zeigarnik-like effects in prospective memory. *Psychological Research, 60,* 192–199.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24,* 336–349.

Mateer, C. A., Sohlberg, M. M., & Crinean, J. (1987). Perceptions of memory functions in individuals with closed head injury. *Journal of Head Trauma Rehabilitation, 2,* 74–84.

Maylor, E. (1990). Age and prospective memory. *Quarterly Journal of Psychology: Human Experimental Psychology, 42A,* 471–493.

Maylor, E. (1993a). Aging and forgetting in prospective and retrospective memory tasks. *Psychology and Aging, 3,* 420–428.

Maylor, E. (1993b). Minimized prospective memory loss in old age. In J. Cerella, J. Rybash, W. Hoyer, & M. L. Commons (Eds.), *Adult information processing: Limits on loss* (pp. 529–551). San Diego, CA: Academic Press.

Maylor, E. (1996). Does prospective memory decline with age? In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 173–197). Mahwah, NJ: Erlbaum.

McDaniel, M. A. (1995). Prospective memory: Progress and processes. In D. L. Medin (Ed.), *The psychology of learning and motivation* (Vol. 33, pp. 191–221). San Diego, CA: Academic Press.

McDaniel, M. A., & Einstein, G. O. (1993). The importance of cue familiarity and cue distinctiveness in prospective memory. *Memory, 1,* 23–41.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. In L. Kvavilashvili & J. A. Ellis (Eds.), New perspectives in prospective memory. *Applied Cognitive Psychology,* S127–S144.

McDaniel, M. A., Glisky, E. L., Rubin, S. R., Guynn, M. J., & Routhieaux, B. C. (1999). Prospective memory: A neuropsychological study. *Neuropsychology, 13,* 103–110.

McDaniel, M. A., Robinson-Riegler, B., & Einstein, G. O. (1998). Prospective remembering: Perceptually driven or conceptually driven processes? *Memory & Cognition, 26,* 121–134.

Meacham, J. A. (1977). Soviet investigations of memory development. In R. V. Kail & J. W. Hagen (Eds.), *Perspectives on the development of memory and cognition.* Hillsdale, NJ: Erlbaum.

Meacham, J. A. (1982). A note on remembering to execute planned actions. *Journal of Applied Developmental Psychology, 3,* 121–133.

Meacham, J. A., & Colombo, J. A. (1980). External retrieval cues facilitate prospective remembering in children. *Journal of Educational Research, 73,* 299–301.

Meacham, J. A., & Dumitru, J. (1976). Prospective remembering and external retrieval cues. *Catalog of Selected Documents in Psychology,* 6(No. 65, Ms. No. 1284).

Meacham, J. A., & Leiman, B. (1982). Remembering to perform future actions. In U. Neisser (Ed.), *Memory observed: Remembering in natural contexts* (pp. 327–336). San Francisco: Freeman.

Meier, B., & Graf, P. (2000). Transfer appropriate processing for prospective memory tests. In L. Kvavilashvili & J. A. Ellis (Eds.), New perspectives in prospective memory. *Applied Cognitive Psychology, 14,* S11–S27.

Messer, D., Kvavilashvili, L., & Kyle, F. (1998, September). *Effects of age and task interruption on event-based prospective memory.* Paper presented at the British Psychological Society Developmental Section Conference, Lancaster University, Lancaster, England.

Morris, P. E. (1992). Prospective memory: Remembering to do things. In M. M. Gruneberg & P. E. Morris (Eds.), *Aspects of memory* (Vol. 1, pp. 196–221). London: Routledge.

Moscovitch, M. (1994). Memory and working with memory: Evaluation of a component process model and comparisons with other models. In D. L. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 269–310). Cambridge, MA: MIT Press.

Nerlove, S. B., Roberts, J. M., Klein, R. E., Yarbrough, C., & Habicht, J. P. (1974). Natural indicators of cognitive ability. *Ethos, 2,* 165–295.

Ohrt, D., & Gronlund, S. D. (1999). List-length effect and continuous memory: Confounds and solutions. In C. Izawa (Ed.), *On human memory* (pp. 105–125). Mahwah, NJ: Erlbaum.

Passolunghi, M. C., Brandimonte, M., & Cornoldi, C. (1995). Encoding modality and prospective memory in children. *International Journal of Behavioral Development, 18,* 631–648.

Rendell, P., & Thompson, D. (1999). Aging and prospective memory: Differences between naturalistic and laboratory tests. *Journal of Gerontology: Psychological Sciences, 54B,* 256–269.

Roediger, H. L. (1996). Prospective memory and episodic memory. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 149–155). Mahwah, NJ: Erlbaum.

Shallice, T., & Burgess, P. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain, 114,* 727–741.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Sodian, B., Schneider, W., & Perlmutter, M. (1986). Recall, clustering and metamemory in young children. *Journal of Experimental Child Psychology, 41,* 395–410.

Somerville, S. C., Wellman, H. M., & Cultice, J. C. (1983). Young children's deliberate reminding. *Journal of Genetic Psychology, 143,* 87–96.

Strong, E. K., Jr. (1912). The effect of length of series upon recognition memory. *Psychological Review, 19,* 447–462.

Terry, W. S. (1988). Everyday forgetting: Data from a diary study. *Psychological Reports, 62,* 299–303.

Underwood, G., Boruch, R. F., & Malmi, R. (1978). Composition of episodic memory. *Journal of Experimental Psychology: General, 107,* 393–419.

Winograd, E. (1988). Some observations on prospective remembering. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues* (Vol. 1, pp. 348–353). Chichester, England: Wiley.

Zeigarnik, B. (1927). Über das Behalten von erledigten und unerledigten Handlungen [On remembering finished and unfinished activities]. *Psychologische Forschung, 9,* 1–85.

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