An Investigation of Prospective Memory in Children

by

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Abstract

Prospective memory performance was investigated in 66 children between the ages of 6 and 12. A developmental progression was found for both time-based and event-based prospective memory. In addition, a difference in performance was found, with the time-based prospective memory task being more difficult than the event-based task. Large order effects were observed on the prospective memory tasks, leading to difficulties in interpretation, and a reduction in sample size. However, the relationship of time-based prospective memory and working memory approached significance. Event-based prospective memory performance was related to performance on a direct retrospective memory task. An implicit memory task was not related to any of the other experimental measures. The relationship of these findings to the existing literature is examined. The problems with the selected tasks are discussed, and suggestions for future studies are proposed.

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Introduction

The Definition of Prospective Memory

Until fairly recently, researchers interested in memory have focused almost exclusively on *retrospective memory*, or recalling information from the past. Neglected has been another type of memory important in everyday life, namely *prospective memory*. Prospective memory is defined as remembering to do something at a particular moment in the future or as the timely execution of a previously formed intention (Einstein & McDaniel, 1996). Common examples are stopping at the store on the way home, relaying a message to a friend, and remembering to keep an appointment with the dentist or to take medication. Remembering to do things is of central importance to our everyday lives because of its inherent involvement in our plans and goal-directed behavior. Most of our behavior is directed at some goal, and it is the flexibility of such planning that distinguishes human behavior (Morris, 1992). Winograd (1988) states that "there can hardly be a more practical aspect of memory than remembering to do things at the appropriate time" (p. 348). The ability to remember such actions bears upon one's self-concept as an efficient, reliable, or well-organized individual (Meacham & Leiman, 1982). When one forgets to carry out actions, often it is the person him or herself who is blamed and branded as unreliable, whereas a failure to describe an event from one's past is blamed on the person's memory rather than directly on the individual (Morris, 1992). Regardless, forgetting intentions is common in everyday life, and may have undesirable or even tragic consequences (Kvavilashvili, 1992). According to some diary studies, nearly half (Crovitz & Daniel, 1984) to 70 percent (Terry, 1988) of memory failures occurring in everyday life involve forgetting intentions versus forgetting information. Nevertheless, there is still a marked disproportion between the frequency of forgetting intentions and the number of experimental studies that investigate prospective memory (Kvavilashvili, 1992).

Many attempts to define prospective memory consist of criteria that distinguish it from the more extensively studied aspects of retrospective memory (Baddeley & Wilkins, 1984). There are undeniable similarities between prospective and retrospective memory in that memory for content is essential to both; however, there are also fundamental differences. Foremost, remembering prospectively involves memory for an intention. Unlike retrospective memory, there must be activation of the intention to perform the task upon the occurrence of the target context. Additionally, the cue for retrieval is often self-initiated as opposed to being initiated by another person, or available in the environment (Cockburn, 1995; Winograd, 1988). In retrospective remembering, cues are usually obvious; subjects are given the cues at the time of retrieval and prompted to recall a prior event. In prospective remembering, subjects must first recognize the cue as a cue before using it to retrieve the associated event. Therefore, although the two tasks share a basic requirement to retrieve previously stored information, prospective memory tasks also require identification of the appropriate cue (Glisky, 1996).

Successful prospective memory requires multiple steps. First, it is necessary to encode and store the intention to perform a future action (content) in a certain context. Second, the individual must activate the intention to perform the task upon appearance of the encoded context. The individual must also inhibit responding until the target context has occurred. Third, they must retrieve and perform the encoded intention, and finally, successful outcome of the task must be recorded in order to prevent repetition of the action (Cockburn, 1995). Therefore, prospective memory not only involves a memory component, but also includes elements of planning, ordering, initiation, inhibition and self-monitoring. In addition, unlike retrospective remembering, prospective memory usually involves remembering to perform an action while one is engaged in another ongoing task. In this way, prospective memory can be conceptualized as occurring in the context of many other activities (Kidder, Park, Hertzog, & Morrell, 1997).

Several studies have failed to find correlations between performance on retrospective and prospective memory tasks (e.g. Einstein & McDaniel, 1990; Kvavilashvili, 1987; Morris, 1984). These results suggest that some of the processes required for the two tasks differ and that they are not dependent upon a single general memory ability. Rather, it suggests that prospective and retrospective memory are sufficiently different in their underlying processes to lead to relatively unrelated performance by the same individual on the two types of tasks (Morris, 1992).

In summary, prospective memory (the execution of intended actions) can be contrasted with retrospective memory (memory for events or information in the past). Prospective memory involves remembering intentions, is often not externally cued, and requires multiple steps. It involves aspects of planning, ordering and initiation, as well as memory. Probably, as a result of these differences, studies have not found significant relationships between performance on retrospective and prospective memory tasks.

Classification of Prospective Memory Tasks

Various classifications have been proposed to capture the important dimensions along which prospective memory tasks may vary. Distinctions have been made between 'pulses' and 'steps' (Ellis, 1988), short-term and long-term recall periods (Einstein & McDaniel, 1996; Ellis, 1996), habitual and episodic activities (Baddeley & Wilkins, 1984; Meacham & Leiman, 1982), and single and dual as well as multiple and compound tasks (Harris, 1984). One major distinction has been made between tasks that require retrieval of an intention at a certain time or within a time window (e.g. take medication at 2 p.m. or after dinner), and tasks that require an appropriate response to some external event that forms the target context (e.g. relay a message to a friend when you see her). These are termed time-based and event-based tasks, respectively (McDaniel & Einstein, 1993).

In time-based tasks, it is hypothesized that a context-checking loop is repeatedly activated to check whether the moment for initiating the intention has been reached. Self-initiation and monitoring of the loop is required in order not to miss the target time. Harris and Wilkins (1982) have proposed a model of the mechanism used for successful performance on time-based tasks: The "Test-Wait-Test-Exit" (TWTE) model of time monitoring. In their study of this model, the participants watched a two-hour film about a hijack. While doing so, they sat with a pile of cards on their knees. On each card was a time; the spacing between successive times was 3 or 9 minutes. The subject's task was to hold up the card at the given time. Harris and Wilkins found that looking at the clock dramatically increased as the target time approached. In the TWTE loop, the individual tests whether the time has arrived for the action and, if not, sets a wait period that is to elapse before the next test (Morris, 1992). The individual repeats this procedure until the time to carry out the intended action has arrived, at which time the loop is exited and the intention is acted upon. In this model, individuals monitor the passage of time using some self-initiated internal mechanism.

In contrast, the event-based task loop is hypothesized to be activated only once, to check the match between cue and target. In event-based tasks, the event provides the external cue for remembering those intentions (Einstein & McDaniel, 1990). It has been suggested that event-based tasks are structurally similar to tests of cued retrospective memory, such as paired associate learning (Einstein & McDaniel, 1996; McDaniel & Einstein, 1993). In both cases, successful remembering requires that the cue and target information (or action) be associated and that aspects of the association be reinstated at retrieval. However, one important difference between prospective and retrospective memory is that in the prospective memory tasks, the individual must spontaneously recognize the event or cue as a stimulus for performing the intended action. In contrast, in retrospective memory situations, the experimenter or some external agent prompts the individual to initiate a directed memory search.

Due to the spontaneous remembering component of prospective memory, some similarities have been noted between prospective and indirect (or implicit) memory tests (McDaniel, Robinson-Riegler, & Einstein, 1998). As in an indirect memory test, a prospective memory task does not involve a direct instruction to interrogate episodic memory in order to formulate a response. Interestingly, an association has been found between performance on an indirect memory test (word-fragment completion) and an event-based prospective memory test (McDaniel & Einstein, 1993). Perhaps, the spontaneous remembering component of prospective memory tasks accounts for the failure to find substantial correlations between direct retrospective and prospective memory tasks (e.g. Einstein & McDaniel, 1990; McDaniel & Einstein, 1993). However, this failure should be interpreted cautiously as experimenters have tended to compare tasks that differ on more dimensions than just the type of memory task (e.g. length of the retention interval, time given for encoding).

In summary, a distinction has been made between time-based and event-based prospective memory tasks. Time-based tasks are proposed to involve a TWTE model of time monitoring, and are fairly dependent on self-initiated process. In contrast, event-based tasks are associated with an external cue, and some similarities have been noted between event-based prospective memory and both conscious and automatic retrospective memory processes.

Prospective Memory and the Frontal Lobes

Many researchers suggest that performance of future intentions is dependent on the frontal lobe structures of the brain. The frontal lobes comprise the largest area of the human brain; they are evolutionarily the most recent structures to emerge and ontogenetically the latest to reach maturity (Glisky, 1996). The prefrontal cortex (the regions anterior and mesial to the motor and speech areas) is thought to support the highest levels of cognitive functioning. The frontal lobes are connected to every other system in the brain and therefore many theorists propose that their overriding function is integrative and executive processing (e.g. Fuster, 1989; Stuss & Benson, 1986; Weinberger, 1993). Consequently, the term 'executive functions' is commonly used to refer to those behaviors presumed to be subserved by the frontal lobes. The frontal lobes are required for formulating plans and supervising non-routine activities. They are responsible for initiating actions, monitoring ongoing behavior, and evaluating outcomes (Glisky, 1996). They are sometimes thought of as the center for working memory (Baddeley, 1986), a place where new information is manipulated and integrated with prior knowledge in preparation for use in tasks.

Most of the systems proposed to be involved in prospective memory have separately or as a whole been linked to the prefrontal cortex. Fuster (1980) suggested that the dorsolateral prefrontal cortex mediates prospective memory functions by temporal ordering of successive responses. Lezak (1982) has proposed four major classes or functional categories of executive capabilities: (a) capacities necessary for formulating goals, (b) capacities involved in planning, (c) capacities having to do with carrying out plans to reach the goals, and (d) capacities for performing these activities effectively. All of these capacities are necessary components of successful prospective memory (see Cockburn, 1995).

It has been suggested that memory, attention and executive functions may be interrelated as past, present and future are interrelated (Eslinger, 1995). Short-term and long-term declarative memory systems are geared toward representing information and events from the past, and attentional systems are necessary to keep certain information in focus for information processing. However, executive functions are almost exclusively future-oriented and are organized for behaviors that may occur in far-distant spatial and temporal settings (Eslinger, 1995). Prospective memory can be conceptualized as one of these future-oriented executive functions, involved in creating plans and realizing future goals.

Working memory is felt by some to be a primary construct underlying executive functions (e.g. Baddeley, 1986; Roberts & Pennington, 1996). Working memory refers to the capacity to hold information in a mental store during active information processing. It can be conceptualized as a cognitive operation in which some bits of information are held in a store characterized by rapid decay in memory while other bits are retrieved from long-term storage (Siegel & Ryan, 1989). Working memory has also been defined as a computational arena for prospectively maintaining the various constraints or situational variables relevant to the current context of the organism (Eslinger, 1995). The construct of working memory implies that certain information remains at the forefront of cognition despite distraction, and hence active in the nervous system for the purpose of guiding appropriate responses. It is prospective rather than retrospective in function (Eslinger, 1995). Therefore, it is likely that working memory is involved in the process of successful prospective memory.

The importance of working memory to frontal functioning has been suggested in a model of prefrontal function proposed by Kimberg and Farah (1993). In this model, a prefrontal insult is proposed to result in the weakening of associations within working memory. The prefrontal damage causes a functional impairment in the strength of various associations active in working memory, including task goals, information about stimuli in the environment, and stored declarative knowledge. This model may account for the types of prospective memory failures seen after frontal lobe damage.

A hierarchical model of prefrontal cortex function has been proposed (West, 1996) in which the integrative function of the prefrontal cortex is supported by four secondary processes: provisional (retrospective) memory, prospective memory, interference control, and inhibition of prepotent responses. The prospective memory component is expectancy-based or goal-oriented. The function of this process is to operate on information derived from the provisional process to prepare the individual for some impending response. The necessary duration of this type of memory is dependent on the initial activation of provisional memory and the time at which the action sequence is executed. A dissociation of impairment between the two types of memory may occur, resulting from the functional organization of the two systems. The prospective aspect of memory is thought to be more highly dependent on the dorsolateral prefrontal cortex, and therefore more susceptible to prefrontal insult (West, 1996). Therefore, a situation can arise in which provisional memory is intact, but prospective memory is impaired, resulting in an inability to incorporate task relevant knowledge in the direction of behavior. This model of prefrontal function shares similar features to models of working memory, where information from long-term storage is retrieved, and then used in cognitive operations to prepare and guide the individual for future activities.

In prospective memory tasks, the individual must be able to adequately plan to execute an action. It has been proposed that working memory is employed to keep the information in a storage loop that can be periodically checked. Disruption in this system may lead to a failure in prospective memory (Raskin & Sohlberg, 1996). A relationship between working memory and prospective memory has also been suggested by Eslinger (1995). Working memory is by definition a process that "temporarily holds on-line constraints relevant to the current context" (Eslinger, 1995). Importantly, Eslinger notes that executive functions include holding goals and solving tasks over a period of time that extends beyond a few minutes and even to different spatial settings. He comments that this type of prospective memory is not well defined in current models, either psychologically or neurobiologically. However, he suggests that it qualifies as a type of working memory since it implies prospective memory-guided rather than sensory-guided responding that is frequently changing yet enduring over a long period of time. Therefore, by this view, prospective memory is an extension of working memory, as it is future-oriented rather than past-oriented. Also, since working memory has been extensively linked to the prefrontal cortex, it follows that prospective memory should be dependent on the prefrontal cortex for adequate functioning.

In prospective memory tasks, the frontal lobes are likely to be involved when demands on working memory are high, preliminary planning is necessary, tasks aren't routine, temporal estimation is required, there is interruption of ongoing behaviors, and environmental or contextual stimuli need to be monitored (Glisky, 1996). Most prospective memory tasks require these frontal functions but to varying degrees. From this hypothesis, two predictions can be derived. First, there should be a correlation between prospective and retrospective memory tasks that involve a significant frontal component, and second, deficits in prospective remembering should be found in patients with frontal lobe damage and in the elderly, to the extent that the prospective memory task requires frontal control (Glisky, 1996).

Evidence of the necessity of the frontal lobes for successful prospective remembering comes from the literature investigating memory deficits among individuals with frontal lobe lesions. Patients with frontal lobe damage often have specific memory deficits. For example, they are often impaired on source memory tasks, memory for temporal order, and memory for frequency of occurrence (e.g. Milner, Petrides, & Smith, 1985; Shimamura, Janowsky, & Squire, 1990; Shimamura, Janowsky, & Squire, 1991). They also seem particularly susceptible to the effects of interference (see Glisky, 1996 for review). Shimamura and colleagues (Shimamura et al., 1990; Shimamura et al., 1991) found a number of specific memory deficits in their patients with frontal lobe damage. These included impairments of short-term memory, free recall, metamemory, memory for temporal order, and source memory. However, new learning ability was not severely affected in patients with frontal lobe damage. The cognitive disorders that they found associated with frontal lobe damage were in planning, problem solving, initiation, perseveration, fluency, cognitive estimation, and disinhibition. These authors suggest that the definition of prospective memory should not only be used to characterize the processes and strategies by which one remembers to perform future actions, but also be broadened to include processes and strategies involved in planning, monitoring and organizing memory.

The authors (Shimamura et al., 1990; Shimamura et al., 1991) note several similarities between prospective memory impairment, the dysexecutive syndrome (Baddeley, 1986) and the notion of disinhibition (Luria, 1966), which other investigators have argued to be the primary impairments associated with frontal lobe damage. For one, prospective memory involves the ability to access, monitor and manipulate associations within a temporal and a semantic context. These memory searches are similar to problem solving tasks in that they require cognitive fluency, initiation, and flexible thinking. Also, it can be supposed that the encoding and retrieval strategies developed in the prospective memory problem solving task would involve discrimination and inhibition of irrelevant information. Therefore, an impairment of inhibitory control would result in prospective memory impairment, because relevant strategies or plans may not be discriminated from inappropriate ones. Also by this view, an impairment of prospective memory would especially affect self-initiated memory tasks. Formulating an intention to carry out a future action involves planning and deciding how and when to perform the activity. Therefore, they suggest that failures of prospective memory may represent a malfunctioning of executive skills as well as of memory (Shimamura et al., 1991). Likewise, Shallice and Burgess (1991) have suggested that patients with frontal lobe lesions show impairments on open-ended "executive" tasks due to problems in the domain of the creation and maintenance of goals and intentions, or their realization at appropriate times (prospective memory), and of planning.

A link between prospective and working memory is again noted, as Shimamura et al. (1991) describe prospective memory, which is needed to manipulate and organize memory, as a "working memory system" dependent on the frontal lobes. This is in contrast to retrospective memory, which is involved in the storage and consolidation of new memories, and is dependent on the middle temporal lobe and the diencephalic midline structures.

Since time-based tasks are more dependent on self-initiated processes, it is expected that subjects with frontal lobe lesions should perform comparatively worse on time-based than on event-based prospective memory tasks. Subjects with frontal lobe damage may fail time-based tasks because they do not initiate retrieval of the encoded intention at the appointed time, but may succeed on the event-based tasks because they are able to utilize cues (Cockburn, 1996).

In a study comparing the performance of controls and patients with frontal lobe damage on a variety of prospective memory tasks, the patients performed significantly worse than controls. However, the difference in performance was largely explained by the patients' poor performance on the time-based tasks. Interestingly, there were no significant differences in accuracy on the event-based tasks (Cockburn, 1996). Also, there was a significant relationship between performance on the event-based prospective memory tasks and free recall. This provides some support for the association proposed by McDaniel and Einstein (1993) between event-based prospective memory and retrospective recall, although the measure used in this study was free rather than cued recall. Unfortunately, since almost all the patients in this study had some degree of frontal lobe involvement, and none had selective temporal lobe pathology, it was not possible to link neuropathology to differential performance on time and event-based tasks.

In another study of a patient with frontal lobe damage (Cockburn, 1995), the failure to successfully perform the time-based prospective memory tasks seemed to be due to a breakdown of the ability to activate the target context as a trigger for activating the intention. When the task conditions required the subject to interrupt and thus stop an ongoing activity, the target context was not sufficiently activated to overcome the level generated by the ongoing activity. The patient was selectively impaired on tasks that required her to spontaneously interrupt an activity or change from one activity to another. This result supports the idea that time-based tasks are more difficult than event-based tasks due to increased reliance on self-initiated retrieval, but it also suggests that time-based tasks may be further divided into those that interrupt and those that complement an ongoing action. The failure attributed to self-initiation in this subject's life may in fact be due to a failure to interrupt an ongoing activity (Cockburn, 1995).

In summary, prospective memory has been extensively linked to the prefrontal cortex. Conceptually, many of the processes underlying time-based prospective memory and working memory are similar. There is also an extensive literature demonstrating time-based prospective memory impairment in individuals with frontal lobe damage. The findings of these studies support the distinction between time and event-based prospective memory tasks, with time-based tasks being more dependent on the integrity of the frontal lobes.

Aging and Prospective Memory

The literature on aging also supports the notion of prospective memory being dependent on the integrity of frontal systems. Research has shown that there is greater loss of neurons in the frontal lobes than in the posterior areas with normal aging, and greater change in frontal lobe functioning than in other abilities (Malloy & Richardson, 1994). The dorsolateral cortex appears to demonstrate a linear decline throughout adulthood, both morphologically and functionally (West, 1996). Older adults perform poorly relative to younger adults on measures of frontal lobe functioning, while performing comparably on tasks of non-frontal lobe function. It has been suggested that this is due to a weakening of inhibitory processes in old age (West, 1996). Craik (1986), has suggested that age-related memory decrements should be especially pronounced for prospective memory tasks, because aging is presumed to disrupt mainly self-initiated processes. In Craik's taxonomy, prospective memory is viewed as the memory task that is most reliant on self-initiated cues.

The literature to date has revealed mixed results regarding age differences on prospective memory tasks (see Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995 for review). This may be because some of the prospective memory tasks that were used in these studies were not as demanding in terms of self-initiated processes as once thought. It is anticipated that age-related differences would be seen primarily on time-based tasks and few if any differences would be evident on event-based tasks. A series of studies comparing the performance of older and younger subjects on time and event-based prospective memory tasks supports this hypothesis (Einstein et al., 1995). In the first study, younger and older participants were engaged in an ongoing task, during the course of which they were asked to press a particular keyboard key every 10 minutes.

There was a clock positioned behind the participants for monitoring the passage of time, and to allow the experimenters to assess time-monitoring behavior. The results demonstrated age-related differences in remembering to press the key on time. Older participants were less likely to remember on time than younger participants were. There was also significantly more time monitoring by the younger subjects during the proximal period before the target time. In all cases, the subjects who forgot to press the key within one minute of the target time failed to monitor the clock during the proximal period (two minutes) preceding the target time.

Einstein and colleagues (1995) performed a second study, essentially exactly the same as the first, except that they used an event-based rather than a time-based task. Subjects had to press the keyboard key every time they saw one of a group of target words on the screen, and a target was presented every 10 minutes. There were no significant differences between the older and younger participants on this event-based task. These results lend further support to the idea that time-based tasks are more difficult than event-based tasks for older subjects because they are more dependent on frontal lobe processes.

In a final experiment, Einstein et al. (1995) directly compared the performance of younger, middle-aged, and older participants on time and event-based tasks. They replicated their results from the previous two studies: on time-based tasks, older participants performed worse than younger or middle-aged participants did, with no differences on the event-based tasks. Also, the younger subjects monitored the clock significantly more in the period preceding the target. The authors conclude that self-initiated thoughts, such as thinking about the prospective memory task and monitoring the passage of time, simply occur less often in older adults. This supports Craik's (1986) view that aging disrupts self-initiated processes. According to the Test-Wait-Test-Exit (TWTE) model, in the absence of external cueing, monitoring or testing the clock appears to be entirely self-initiated. To the extent that this is true and that older participants are deficient in self-initiated processes, one would expect less monitoring by the older participants.

However, some studies have found an age-related decline in event-based prospective memory performance (e.g. Mantyla, 1994; Maylor, 1993; Maylor, 1996). It has been suggested that the magnitude of age differences in prospective memory might be related to task complexity (Einstein & McDaniel, 1990). For example, Einstein et al. (1992) varied the number of target words that participants were required respond to. They found significant age differences when there were several targets to be remembered, but not when there was a single target word. These authors suggest that this result may be due to the difficulty of the retrospective component of the task for the elderly subjects (i.e. remembering what they have to do), and not the prospective component (recognizing the cue). Older adults were less likely to remember the full set of cue words, such that failure to respond was a result of forgetting the target to which they were to respond rather than of forgetting to respond when cued. Another study (Einstein, 1991, as cited in Einstein et al., 1992) supports this view, since in this study, the targets were well remembered by the elderly adults, and no significant age-related decline was demonstrated. In addition, Kidder et al. (1997), reported that prospective memory was more disadvantaged for older adults than younger ones when the number of prospective targets was increased.

It has also been suggested that the salience of the cue can contribute to whether age differences are found. By making a cue less salient, it increases the demands on self-initiation, thereby increasing the gap between younger and older participant's performance. Mantyla (1994) varied item typicality of targets, under the assumption that less typical members of a semantic category would require a greater degree of self-initiation than typical prospective memory targets. He found significant age differences only on the low typicality, or high self-initiation, condition. These results are interpreted as suggesting that age-related decrements in prospective memory occur under task conditions in which the resource requirements for self-initiated retrieval operations are fairly high. Maylor (1996) has suggested that an age-related impairment occurs whenever the prospective memory task and the background task in which it is embedded are processed in qualitatively different ways. Therefore, older adults may be particularly impaired at shifting constantly, which is presumed to be self-initiated, from one level or type of stimulus to another.

In summary, the effects of aging on prospective memory are still being investigated. In general, elderly persons perform comparatively worse on time-based than event-based prospective memory measures, presumably due to a decline in self-initiation and self-monitoring. However, some recent studies have also suggested a link between event-based tasks and self-initiation and/or working memory. Perhaps a better way of conceptualizing differences between the types of prospective memory tasks may be the amount of self-initiation demands that are required. While it is usually the situation that time-based tasks are more dependent on self-initiated retrieval and working memory, it has been shown that event-based tasks can be created to tax the same systems.

Prospective Memory in Children

Few investigations of prospective memory have been undertaken with children. One notable exception is the seminal research by Ceci and Bronfenbrenner (1985). In this study, children aged 10 and 14 were asked to perform future activities after 30 minutes. Children's clock checking behavior during the waiting period was monitored in the laboratory and in the children's homes. It was found that the majority of children employed the TWTE strategy of clock checking described by Harris and Wilkins (1982). The only exception was 10-year-old children in the laboratory, who engaged in what the authors term "anxious time monitoring", in which clock checking increased linearly from beginning to target time, and was associated with more clock checking overall. This may be due to the children's increased concern about the seriousness of errors in the laboratory. This is in contrast to the "strategic time monitoring" or TWTE strategy that the children used in the other scenarios. They also noted that late arrivals (i.e. those who had prospective memory failures) did not engage in strategic time monitoring. Therefore, these findings demonstrate that children as young as 10-years-old utilize a similar strategy for time-based prospective memory tasks as adults do. Ceci and colleagues (Ceci, Baker, & Bronfenbrenner, 1988) extended their findings on prospective memory in children by engaging children in time-based prospective memory tasks and then investigating the impact of manipulating the clocks to run faster or slower than they should. The authors concluded that children were able to calibrate their sense of time to clocks that ran within a third of normal limits, and still employed the TWTE strategy of time monitoring. However, when they varied the clock by as much as fifty percent, the children became suspicious and increased their clock-checking behavior dramatically.

A study of deliberate reminding was undertaken with 2, 3, and 4-year-olds (Somerville, Wellman, & Cultice, 1983). Caretakers asked their children to remind them to do something at a future time, on eight separate occasions. The child was provided with a combination of temporal and circumstantial cues to perform the reminding tasks (e.g. when we go to the store tomorrow morning). These cues were given to the child verbally, just once for each task. The tasks varied in length of time to recall (short delay-one to five minutes; long delay-morning to afternoon, or evening to next morning) and in interest level (high interest-remind me to buy candy at the store, low interest-remind me to bring in the wash after your nap). They found that high interest tasks were performed correctly more often than low interest tasks, with short delays more often than long delays. However, effect of interest level had a much more pronounced effect than the length of the delay. Also, there were no significant age differences. The children showed considerable competence on these tasks: On the high interest, short delay tasks, children remembered on average 73% of the time without prompting. Therefore, this study is evidence that even young children are capable of adopting a deliberate set to remember.

Another prospective memory study was performed with 6- and 8-year-old children (Meacham & Dumitru, 1976). The children were asked to remember to place a drawing in a contest box that they had previously seen, when returning to the classroom. They found that 8-year-olds remembered significantly more often than 6-year-olds. Similarly, Meacham and Columbo (1980) asked 5- and 7-year-olds to remind the experimenter at the end of the activity to open a "surprise box", and after the intervening seven minute period, they noted how many children provided the requested reminder. In contrast to the previous study, they did not find any significant age differences. However, the authors note that it is likely that a more marked age effect would be found with older children. They also found significantly better performance in children who were provided with an external cue for remembering.

Except for the study by Ceci and Bronfenbrenner (1985), there have been few investigations of time-based prospective memory in children. Also, in Ceci and Bronfenbrenner's study, the children had already developed adult time-monitoring strategies. The developmental trajectory of these abilities had not been systematically studied nor had the effect of different types of prospective memory tasks on children's performance been assessed. Given that prospective memory is an essential component of future goal-oriented behavior, a clearer understanding of how and when children develop these skills is essential to understanding child cognitive development.

As stated previously, many similarities have been noted between prospective memory and executive functions, which are purported to be dependent on the frontal lobes. Results of numerous studies suggest that these executive abilities mature in a stage-like and protracted fashion throughout childhood, with different abilities maturing at different times (e.g. Becker, Hynd, & Isaac, 1987; Levin et al., 1991; Passler, Isaac, &

Hynd, 1985; Welsh, Pennington, & Groisser, 1991). Working memory, which has been proposed as one of the essential abilities underlying executive functions, and as integral in prospective memory, appears to follow a developmental trajectory similar to other abilities dependent on the frontal lobes (e.g. Case, 1985; Case, 1992; Fuster, 1985; Welsh & Pennington, 1988). However, virtually nothing was known about the development of prospective memory and how it relates to the development of working memory.

The Present Study

Prospective memory is known to be important for planning and goal-directed behavior in everyday life. Toddlers are normally not expected to engage in such goal-directed behaviors, but by adolescence these skills are expected. It seems likely that prospective remembering abilities are required and therefore develop as children begin to have the freedom and the responsibility to choose between various actions (Meacham & Colombo, 1980). However, what was needed was a closer consideration of the contexts and mechanisms by which young children first attempt to remember to perform future actions, and how this ability develops over time.

Prospective memory has been extensively linked to the prefrontal cortex in adults, which is necessary for formulating plans and carrying out goal-directed activities, and is thought to be the center for working memory. Numerous studies have demonstrated that rudiments of executive functions are present at an early age, and that these skills develop in a stage-like progression throughout childhood. However, little was known about the development of prospective memory and how it relates to the development of executive functions in children. To date, no studies have directly examined the development of prospective memory and executive functions concurrently in children. The normal development of prospective memory had yet to be been examined across a large developmental age range, nor had the effect of type of prospective memory task in children been studied. Knowledge regarding the normal developmental trajectory of these abilities may aid in producing a clearer picture of the development of memory and executive functions. Furthermore, it may lead to a better understanding of the nature of prospective memory impairments demonstrated in individuals with frontal lobe dysfunction and in the elderly. Also, this information may be useful in understanding the problems encountered in children with disorders hypothesized to involve some frontal component, such as in Attention Deficit Hyperactivity Disorder and Traumatic Brain Injury.

The present study investigated the developmental trajectory of prospective memory throughout childhood. The relationship between performance on different prospective memory tasks, a working memory task, a retrospective memory task, and an implicit memory task was examined. It was hypothesized that with increasing age, performance on the prospective memory tasks would improve. In addition, a distinction was predicted to emerge between time-based and event-based prospective memory performance, with performance on the event-based task being superior to that on the time-based task. Time-based tasks are hypothesized to be more difficult than event-based tasks (Kvavilashvili & Ellis, 1996), and individuals with frontal lobe dysfunction have more difficulty with time-based tasks. Since time-based tasks are hypothesized to be dependent on the frontal lobes, younger children should have more difficulty with these types of tasks as the prefrontal cortex has a protracted course of development throughout childhood.

It was hypothesized that time-based prospective memory performance would correlate highly with performance on a working memory task. Working memory and time-based prospective memory have both been linked to the prefrontal cortex, and many researchers have noted similarities between the working memory and the prospective memory systems. In contrast, performance on the event-based task was hypothesized to be correlated with performance on a cued-recall retrospective memory task. Dissociations have been noted between performance on event-based and time-based prospective memory tasks, which suggests that they may be dependent on different underlying processes. In addition, an implicit memory task was included to examine the relationship of event-based prospective memory to implicit memory, as some similarities have been noted between these memory systems.

Method

Participants

Sixty-six normal children, ranging in age from 6 to 12, were recruited for the present study. Mean age was 9.02 (*SD* = 1.82, Range = 6.04 - 12.29). Mean IQ was 106.09 (*SD* = 11.21, Range = 84 - 141). There were roughly equal numbers of males and females across different ages ($Chi^2_{(5)} = 3.99$, $p = .55$) (see Table 1). Children were recruited for participation through advertisements in a local parent magazine, distributed flyers, and through the Greater Victoria School Board. Testing was conducted individually, in a quiet room, at the University of Victoria. All children were compensated with a small monetary stipend of $5.00.

Participants' medical and educational history was screened through the completion of a child history questionnaire by their parents. Volunteers with prior histories of significant neurological, psychiatric, or intellectual concerns were excluded from the sample, resulting in a total of two excluded children, one due to significant neurological trauma, and the other because of intellectual concerns. The number of pregnancy complications, neonatal complications, and history of medical problems was comparable within the age groups (Chi^2 p values ranged from .10 to .66). Past and present educational history revealed that the number of participants engaged in French immersion ($Chi^2_{(5)} = 5.52, p = .36$), gifted programs ($Chi^2_{(5)} = 6.01, p = .31$) and learning assistance ($Chi^2_{(5)} = 8.64, p = .12$) did not vary significantly with age.

TABLE 1

Description of the Sample

Age	Number		IQ
	Males	Females	Mean FSIQ (SD)
6	8	4	104.92 (13.41)
7	6	4	108.90 (17.19)
8	4	6	105.20 (7.44)
9	7	4	103.00 (12.37)
10	5	8	108.54 (7.60)
11*	4	6	105.80 (7.58)
Total Sample	34	32	106.09 (11.21)

*Note: There are three 12-year-old children (ages 12.04, 12.27, 12.29), combined with the 11-year-old age group.

Measures

Time-Based Prospective Memory.

In this study, the child was engaged in a car-racing task called "CyberCruiser" (Kerns, 1998), similar to many computer games. The child was told that goal of the game was to gain as many points as possible by maintaining the vehicle on the road while avoiding obstacles. However, the secondary goal of the task was to make sure that the car did not run out of gas. The importance of this was stressed to the children by telling them that if they ran out of gas, they would lose all their points accumulated thus far. The gas gauge could be checked by pressing a particular key on the joystick but only remained on the screen for 1.5 seconds, and pressing another key could refuel the car. However, the tank could only be filled once the gauge showed that it was less than 1/8 full, indicated by a red area on the gauge. The task was played for seven and a half minutes, with the gas potentially running out once every one and a half minutes. Therefore, there was the potential for the child to run out of gas five times over the course of the task. Tabulated scores were the number of gas gauge "checks" and the number of times children ran out of gas.

The "car-racing" paradigm was felt to be engaging to children of this age, and it was expected that the participants would become involved in the primary task, thereby making the secondary prospective memory task more difficult. In a previous study (Kerns, Wilde, & Archibald, 1998) using a slightly shorter version of this task (5 minutes in duration) with 89 children between the ages of 6 and 12, there was a trend for children to run out of gas less often as they got older. Therefore, there was support that this task was sensitive to age, but it was felt that the range of responses was possibly restricted. Thus, the task was lengthened, extending the number of times that the child could potentially run out of gas.

Event-Based Prospective Memory.

This task was similar to the time-based task described above, except that the game was changed to create an event-based task. This modification was made by having children fill their gas whenever they saw a yellow bus on the road. The task was played for seven and a half minutes, and a target "bus" appeared on the road every one and a half minutes. Children were required to press the "fill" button while the bus was on the screen (same duration as the time in the "red area" in the time-based task). If they did not respond during this time, they ran out of gas. The score on this measure was the number of times children forgot to fill their gas when they saw a bus.

A bus was chosen as a cue for this task because it was part of the ongoing process of the game, and yet was different enough from the other vehicles on the road so as to be a clearly distinct event. The event-based task was designed to be as similar as possible to the time-based task in all domains except for the retrieval context. Therefore any differences in performance could be attributed to the variable of interest.

The time and event-based prospective memory tasks were counterbalanced across age, such that half the children played the time-based task at the beginning of the session and the event-based task at the end of the session, and half vice versa.

Working Memory.

This working memory task was a variant of one that has been used in a number of studies with different clinical populations (e.g. Owen et al., 1993; Owen, Downes, Sahakian, Polkey, & Robbins, 1990; Owen et al., 1992; Owen, Morris, Sahakian, Polkey, & Robbins, 1996; Owen, Sahakian, Semple, Polkey, & Robins, 1995; Sahakian et al., 1988). Two conditions of this task were used. In the spatial working memory task, participants were presented with a number of boxes on the computer screen. They were told that the object of the task was to find the "money" hidden inside the boxes to fill up "the bank" (a column along the side of the screen). The participants were instructed to search through the boxes until they found the money, at which point that money would be added to their bank and more money would be hidden. They were also told that once money was found inside a particular box, that box would never again be used to hide money. Since every box was used once to hide money, there was the same number of "moneys" as there were boxes in each trial. One practice trial with four boxes was performed to make sure the child understood the instructions of the task. Then, two trials of eight boxes were performed.

In the visual working memory task, participants were presented with a number of abstract symbols on a computer screen. The children were instructed that they were to find the money hidden "inside" the symbols. Again, they could look for the money by clicking on a symbol. However, after they "looked in" a symbol, the symbols would change positions on the computer screen. Therefore, the participant had to remember which symbol the money was found "in", not the location on the screen where the money was found. The participant was given a practice trial with four symbols, followed by the administration of two trials of six symbols. The variables of interest in this task were two different types of search errors. Firstly, a subject could return to a box (or symbol) already opened and shown to be empty within an individual search sequence (within-search error). Second, after locating the money in a trial, a subject could then return to a box (or symbol) in which money had previously been found (between-search error). The number of between-search and within-search errors was summed within each type of task, as well as across all four trials.

The Arithmetic subtest of the Wechsler Intelligence Scale for Children - Third Edition (WISC-III) (Wechsler, 1991) has been interpreted as a measure of working memory in children (see Becker, 1994). Thus, this task was included to provide construct validation to the working memory measures that were used in this study.

Retrospective Memory.

The Visual Learning subtest of the Wide Range Assessment of Memory and Learning (WRAML) (Sheslow & Adams, 1990) was used as a measure of retrospective memory in this study. The WRAML is a well-standardized psychometric instrument designed to measure children's memory abilities between the ages of 5 and 17. The Visual Learning subtest demonstrates high reliability (coefficient α median = .88). It also shows a developmental progression, as there is a significant correlation between age and score on the subtest in the standardization sample (8 & younger: $r = .25, p < .001$; 9 & older: $r = .06, p < .015$).

In this task, the individual was presented with a 4x4-design board, with yellow covers over the designs. The experimenter removed each cover one by one, and asked the participant to try to remember each design they saw and its location. After exposing each design, the experimenter showed the participant pictures of each design on cards (one at a time) and asked the child to point to where the design was on the board. If the child was correct, the experimenter removed the yellow cover to expose the design. If the child was incorrect, the experimenter corrected their error by showing them where the design was located. There were four immediate trials and one delayed recall trial. Variables of interest were: The total number of correctly located designs on the immediate trials, which was also converted to an age-based scaled score ($M = 10$, $SD = 3$), the number of correctly located designs on the delay trial, and the percent retained (savings) on the delay trial (compared with the child's best trial). For individuals who remembered more on the delay trial than on their best learning trial, a savings score of 100% was given (i.e. participants could not obtain a savings score greater than 100%).

This task was selected for use in this study, firstly, because the WRAML is a standardized instrument of children's abilities, and therefore suitable for use with children in the age range under study. In addition, since nonverbal working memory and prospective memory tasks were selected, it was appropriate to have a nonverbal retrospective memory task for comparison purposes.

Implicit Memory.

It has been suggested in the literature that event-based prospective memory tasks may include a spontaneous, non-strategic remembering component. Therefore, with the inclusion of an implicit memory task in the study, prospective memory performance could be compared to automatic, as opposed to strategic, retrieval processes. A fragmented pictures paradigm developed by Snodgrass and colleagues (Snodgrass, Smith, Feenan, & Corwin, 1987) was employed. In this task, participants were shown a number of series of diagrams of objects, which were all well known for children in this age range (i.e. animals and household objects). The diagrams of objects were presented at 8 levels of degradation with the first being the most degraded (missing significant components of the object). The next 7 diagrams in the series gradually added more information until, by the last one, the entire object was clear. The test was broken down into two phases. In the first phase, participants were presented with the first diagram in a series, and tried to identify the object. If they could not identify it, they were shown the next diagram in the series, which had more detail. As soon as the participant could correctly identify the object, the series of diagrams for the next object commenced. In the second phase (the test phase), participants were presented with a test set of 30 series of diagrams of objects consisting of the 15 objects used previously in the training set (old set), and 15 new objects (new set). Again, the goal was to identify each object as soon as possible. Identification thresholds for the "train", "new", and "old" stimuli sets were calculated based on an average of how many diagrams in the series were required for identification. Usually, a measure of perceptual learning (implicit memory) is calculated by subtracting the threshold for the "old" stimuli from the "new" stimuli. This method of calculation is used, because some skill learning normally occurs (i.e. "new" thresholds being lower than "train" thresholds). However, in this study, the calculated score for this task was the "old" score subtracted from the average of "train" and "new" scores. This method was used because there was a concern that the "new" set used in this study was more difficult than the "train" set (i.e. there was no effect of skill learning, and usually the opposite is noted). Therefore, using the "new" set as a baseline would have exaggerated the priming effect in this sample. Thus, performance on the "train" and "new" sets was averaged, to create a more reliable baseline measurement.

A nonverbal implicit memory task was selected as opposed to a verbal one due to the varying levels of reading ability that were present in the sample, in addition to facilitating comparisons with the other nonverbal measures. In addition, this paradigm has been used successfully with children in the age range under study, and consistent priming effects have been observed (e.g. Gonzales, 1997; Wippich, 1989, cited in Parkin, 1993; Parkin & Streete, 1988).

General Cognitive Functioning.

All subjects were administered the Kaufman Brief Intelligence Test (K-BIT) (Kaufman & Kaufman, 1990) as a measure of intellectual functioning. It is an individually administered, brief measure of verbal and nonverbal intelligence for individuals ages 4 to 90. The K-BIT IQ score has demonstrated reliability (split-half r = .94; test-retest r = .94) and validity, correlating highly with longer standardized intelligence tests (WISC-R: r = .80; WAIS-R: r = .75). A cognitive measure was included to ensure that the sample of children studied fell within the average range. An age-based standard score (M = 100, SD = 15) was calculated for full-scale IQ (FSIQ).

Results

Data Screening

Prior to analysis, all measures were examined for accuracy of data entry, missing values, and fit between distributions and the assumptions of analysis. The data set was complete for all participants. One univariate outlier was identified on the visual learning savings score (as defined in Tabachnick & Fidell, 1996). To reduce the influence of this outlier, it was assigned a raw score one unit larger than the next most extreme score on this variable. No multivariate outliers were identified. Number of prospective memory failures on the event-based task (bus) was significantly positively skewed. The percentage savings score for the visual learning subtest demonstrated significant negative skewness, and positive kurtosis (with many individuals reaching 100% savings). All other variables did not deviate significantly from normality.

Task Associations with Demographic Variables

The association between the skills assessed by the experimental measures and the demographic variables, measured by the Child History Questionnaire, was explored through regression analysis. The results revealed that there were no significant effects of gender (*p* values ranged from .24 to .95).

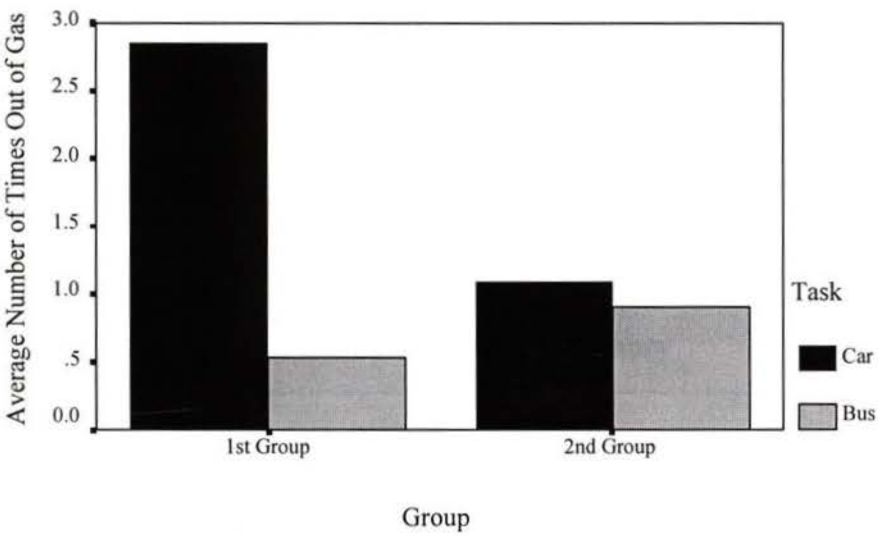
Except for the expected relationship between enrollment in gifted programs and IQ ($F = 13.07$, $p = .001$), and the negative relationship between learning assistance and IQ ($F = 6.49$, $p = .01$), medical and educational history were not meaningfully related to test performance.

Order Effects

Presentation of the event and time-based prospective memory tasks was counterbalanced to ensure that the effects found on experimental measures were not due solely to order. A repeated measures MANOVA was performed to investigate the presence of order effects. The main effect of group was significant ($F = 9.11$, $p = .004$), indicating that there was indeed a difference in performance on the tasks depending on which order they were presented in. There was a significant effect for number of prospective memory errors ($F = 42.86$, $p < .001$), showing that children performed better on the event-based (bus) task than the time-based (car) task. The interaction effect was also significant ($F = 30.65, p < .001$), revealing a significant order effect. As demonstrated in Figure 1, performance on the car task was significantly better in the group that participated in the bus task first. No significant difference in bus performance was noted between the groups, perhaps due to the ceiling effect observed on the bus task.

FIGURE 1

Order Effects on Prospective Memory Tasks



Car = Time-Based Task; Bus = Event-Based Task
1st Group = Car Task First; 2nd Group = Bus Task First

Due to the large effect of order of presentation, it was decided that order effects would confound analysis of the second prospective memory task. It is probable that in both situations, participation in the first prospective memory task somehow altered performance on the second task. Therefore, the car task was examined only in the group that participated in this task first (1st Group), and likewise for the bus task (2nd Group).

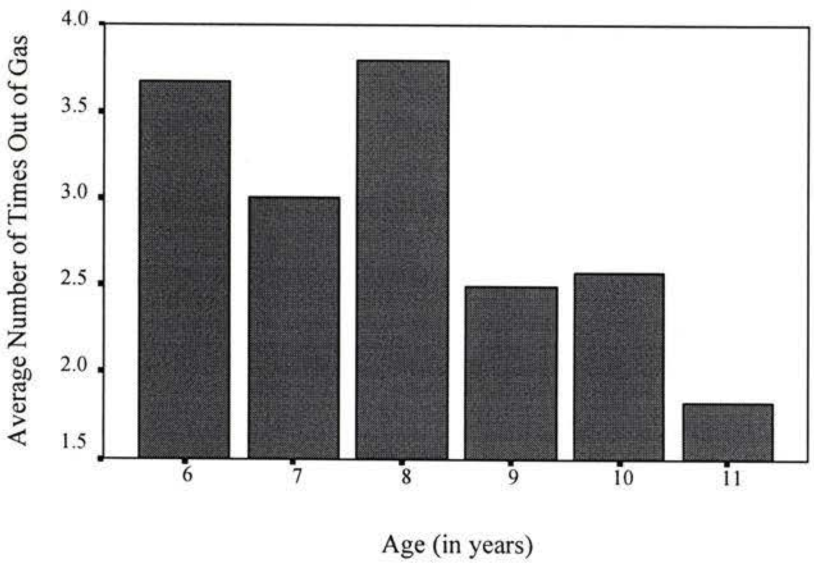
These groups were also noted to differ significantly on FSIQ ($t = 3.08, p = .003$), with the first group (*M* = 109.80, *SD* = 11.80) having a higher IQ than the second group (*M* = 101.90, *SD* = 8.95). There was no significant difference in performance between groups on any of the other experimental measures.

Time-Based Prospective Memory Task (Car Task)

Regression analysis revealed that age accounted for a significant proportion of the variance in time-based prospective memory performance ($F = 3.99$, $p = .05$, *Adjusted* $R^2 = .08$), indicating that prospective memory performance improved with age. The relationship between age and time-based prospective memory is demonstrated in Figure 2.

FIGURE 2

Age and Time-Based Prospective Memory



The hypothesis that working memory[1] and time-based prospective memory would be correlated was examined via regression analysis. A relationship was found between these two variables, although it failed to meet accepted significance levels ($F = 3.34$, $p = .077$, *Adjusted* $R^2 = .06$). However, reduced sample size, and hence low power, may be a contributing factor to the significance of this finding. Since both time-based prospective memory performance (see above) and working memory performance ($r = -.47$, $p = .004$) were significantly related to age, the relationship between these two variables was examined with age as a covariate. With the variance associated with age removed, the relationship between time-based prospective memory and working memory performance did not reach significance ($t = 1.03$, $p = .32$).

Time-based prospective memory performance was also found to be significantly related to Arithmetic ($F = 4.36$, $p < .05$, *Adjusted* $R^2 = .09$), although not in the absence of age ($t = .94$, $p = .36$).

It was hypothesized that the number of checks on the time-based task would be related to number of prospective memory failures (i.e. times out of gas), with individuals who checked more performing better on the task. This relationship was significant ($r = -.61$, $p < .001$), and is demonstrated in Figure 3. Not suprisingly, number of checks also increased with age ($r = .43$, $p = .01$), therefore the relationship between checks and failures was examined with age partialled out. The relationship remained significant (partial $r = -.55$, $p = .001$).

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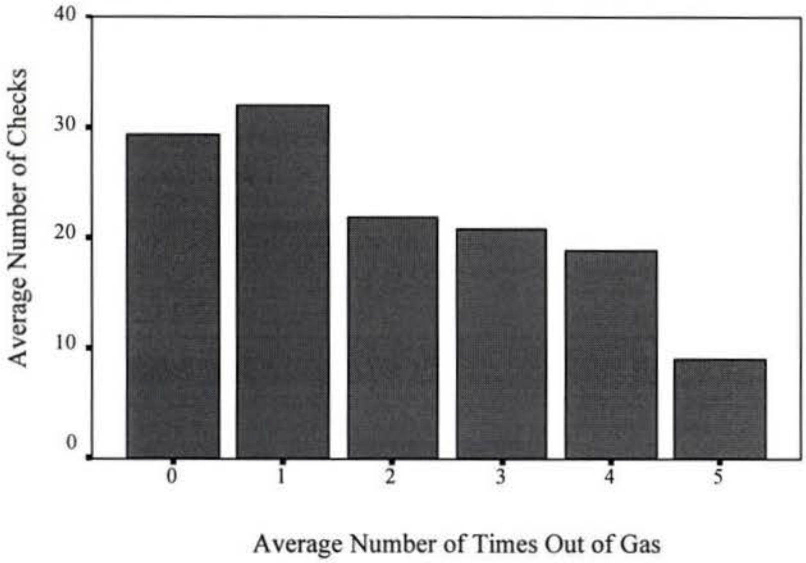
[1] Analysis of performance on the working memory tasks (in the entire sample) led to the determination that the boxes task was the most valid measure of working memory, as it correlated highly with another standardized measure of working memory (WISC-III Arithmetic: $r = -.57$, $p = .001$). The symbols task was not related to performance on Arithmetic ($r = -.17$, $p = .18$). Therefore, performance on the boxes task (between-search and within-search errors combined) was used as a measure of working memory in all analyses.

FIGURE 3

Checks and Times Out of Gas on Time-Based Task



Event-Based Prospective Memory Task (Bus Task)

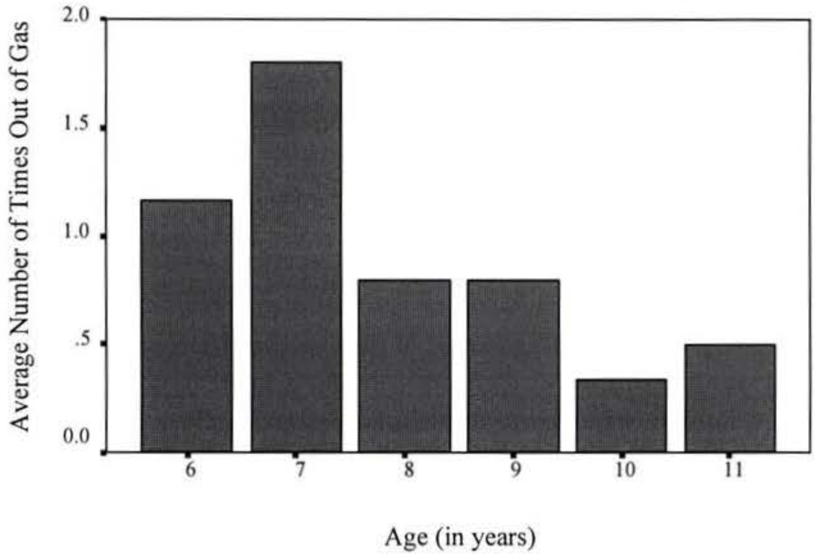
Regression analysis revealed that event-based prospective memory performance improved with age ($F = 4.47, p = .04$, *Adjusted* $R^2 = .10$). The relationship of age and performance on this task is demonstrated in Figure 4.

The hypothesis that event-based performance would be related to retrospective memory was analyzed via regression. There was a significant relationship between bus performance and both the visual delay score ($F = 9.06, p = .005$, *Adjusted* $R^2 = .21$), and the visual learning total score ($F = 6.24, p = .02$, *Adjusted* $R^2 = .15$). Since the visual learning total score was significantly related to age, the relationship with bus performance was examined after controlling for age. When the variance associated with age was removed, the relationship between bus performance and the visual learning total score failed to reach accepted significance levels ($t = -1.79, p = .08$).

No relationship was found between performance on the event-based task and either working memory performance ($r = .22, p = .23$) or Arithmetic ($r = -.15, p = .43$).

FIGURE 4

Age and Event-Based Prospective Memory



Relationship of Prospective Memory Tasks

The hypothesis that the time-based prospective memory task would be more difficult than the event-based task was examined via an independent samples *t*-test. These groups were found to differ significantly ($t = 5.67, p < .001$), with the group performing the car task demonstrating significantly more errors ($M = 2.86, SD = 1.65$) than the bus task group ($M = .90, SD = 1.04$). The inclusion of IQ as a covariate in the analysis did not reduce the significance of this finding.

The relationship of age to differential task performance was examined via ANOVA. The interaction of age and task performance was not significant ($F = .67, p = .65$), indicating that differences in task performance did not vary significantly across age groups.

Implicit Memory Task

The relationship between implicit memory and the other memory measures was examined via zero-order correlations. There was no significant relationship between implicit memory performance and age or any of the other experimental measures.

Discussion

The present study sought to investigate the development of prospective memory in children, as well as the relationship of prospective memory to other, more extensively studied, memory systems.

The presence of large order effects on the prospective memory tasks led to considerable difficulty in interpretation. Originally, the study was designed to permit analysis of direct relationships among tasks (i.e. within individuals). However the significant differences in prospective memory performance depending on order of presentation suggested that due to practice effects, the second prospective memory task was likely not measuring a comparable skill to the first. The presence of order effects suggests that performance on the second task was likely mediated by factors in addition to prospective memory skill (e.g. familiarity with the task, sensitivity to the time interval, etc). Since participation in one prospective memory task somehow altered performance on the second prospective memory task, it was necessary to examine only the first task that was performed. Thus, the time-based (car) task was examined in the proportion of the sample that participated in the car task first, and likewise for the event-based (bus) task. As such, the magnitude of analyses that could be performed (i.e. examining the relationship among various tasks within the same group) was limited. Moreover, the sample size for each analysis was essentially reduced by half, thus resulting in diminished power.

As predicted, a developmental progression of prospective memory performance was found. Both time-based and event-based prospective memory tasks demonstrated a significant age effect. This supports the notion that prospective memory skill improves with age, and extends the previous studies of prospective memory in children (e.g. Meacham & Colombo, 1980; Meacham & Dumitru, 1976; Somerville et al., 1983). While other studies had examined event-based prospective memory in young children, a large age range had never been systematically examined, and therefore the developmental trajectory of prospective memory had never been reported. This study also extends previous recent research (Kerns, 1998; Kerns et al., 1998) on time-based prospective memory performance in young children, and replicates findings of a developmental progression of this skill. Ceci and Bronfenbrenner's study (1985) involved older children who demonstrated close to adult levels of performance, and therefore did not allow the examination of the development of such skills.

Despite some promising results using these prospective memory tasks, considerable order effects were revealed. This suggests that these tasks may not be valid when multiple trials are given in a single setting, and refinement of the task will be necessary to reduce this effect. One potential hypothesis for the order effects is that, on both prospective memory tasks, the target context appeared at 1.5-minute intervals. This design was purposeful, such that the tasks would be as similar as possible in all domains except for the retrieval context. However, it is possible that the individual was "trained" to become sensitive to this time interval, thus facilitating performance on the second prospective memory task. This hypothesis could be investigated by varying the time between the prospective memory targets, and determining the effect of this manipulation on the magnitude of the order effects.

In addition to the order effects, the event-based task demonstrated ceiling effects, such that the average failure rate was less that 1 out of 5 potential failures. Thus, manipulating the parameters of the task to vary the difficulty level would be useful. A manipulation such as making the event less distinct, perhaps by varying the color of the stimulus, might increase the difficulty. The characteristics of the cue used in an event-based prospective memory task have implications for performance (see Brandimonte & Passolunghi, 1994 for review). It has been hypothesized that successful performance in prospective memory tasks depends on the triggering of the action by the target event. Research has indicated that varying the nature of the cue (Einstein & McDaniel, 1990; Mantyla, 1994; Maylor, 1990; McDaniel & Einstein, 1993), has a marked influence on prospective memory performance. In a series of experiments performed by Brandimonte and Passolunghi (1994), the effects of cue distinctiveness and familiarity were examined. They found that both cue familiarity and/or cue distinctiveness had a significant impact on performance (i.e. unfamiliarity and/or distinctiveness facilitated performance). It would be interesting in future studies to investigate the relationship between age and cue characteristics in event-based tasks.

In addition, it would be worthwhile to examine event-based prospective memory performance in preschool-age children, as the age relationship suggests that in younger children the magnitude of errors would increase. On a similar note, there was no "leveling-off" of performance on the time-based task in this age range, therefore the performance of adolescents on a time-based task would be interesting, to determine when a plateau of performance occurs.

It has been suggested in the literature that time-based tasks are generally more difficult than event-based tasks, as they are more dependent on self-initiated processes (e.g. Kvavilashvili & Ellis, 1996). This difference in performance was demonstrated in the present study. The time-based task was found to be more difficult than the event-based task. Thus, as these two tasks were essentially the same except for the retrieval context, it supports the distinction of a fundamental difference between time-based and event-based tasks, which has been proposed in the literature (see McDaniel & Einstein, 1993). It is predicted that the self-initiated component of the time-based task is the primary reason for its increased difficulty.

In terms of time-based performance, the hypothesis that number of clock checks would be related to performance was corroborated, with individuals who checked the clock more frequently performing better on the task. This relationship remained significant even after statistically controlling for age. This finding confirms results from studies with elderly patients (e.g. Einstein et al., 1995). It is hypothesized that the reason for diminished clock checking is related to impairments in self-monitoring and self-initiation. Therefore, it suggests that one reason individuals perform poorly on this task is due to difficulties in self-monitoring.

Although two working memory tasks were employed in this study, only the spatial task appeared to be a valid measure. The spatial task was highly related to an established measure of working memory (WISC-III Arithmetic) from the literature. In addition, a significant relationship with age was demonstrated, which is consistent with the findings of a developmental trajectory of working memory (e.g. Case, 1985; Case, 1992; Fuster, 1985; Welsh & Pennington, 1988). The non-spatial (visual) working memory task did not show a relationship with Arithmetic. One potential problem was that the non-spatial task was noted to be extremely difficult for this population, and many children appeared to responding randomly. This paradigm was a modification of a task used with adult populations, and the necessary difficulty level for this age range was not well established. Therefore, it is likely that the non-spatial working memory task in this study was not valid nor comparable to those used in other studies.

A trend, albeit non-significant, was found between time-based prospective memory and performance on the spatial working memory task. In addition, a significant relationship was found between Arithmetic, a measure of working memory, and time based performance. However, after controlling for age, neither relationship remained significant. Numerous similarities have been noted in the literature between time-based prospective memory and working memory, with both abilities thought to be dependent on the integrity of the frontal lobes of the brain (e.g. Eslinger, 1995; Glisky, 1996; Raskin & Sohlberg, 1996; Shimamura et al., 1990; Shimamura et al., 1991). For example, Eslinger

(1995) suggests that prospective memory qualifies as an extension of working memory. Shimamura and colleagues (Shimamura et al., 1990, Shimamura et al., 1991) describe prospective memory, which is needed to manipulate and organize memory, as a "working memory system" dependent on the frontal lobes. Fuster (1980) suggests that the dorsolateral prefrontal cortex mediates prospective functions by temporal ordering of successive responses.

In addition, time-based prospective memory impairment has been demonstrated in individuals with frontal lobe lesions and in the elderly (e.g. Cockburn, 1995; Cockburn, 1996; Einstein et al., 1995; Furst, 1986; McDaniel & Einstein, 1993). Thus, a significant relationship between the working memory and the time-based prospective memory tasks was expected. However, the presence of order effects on the prospective memory task made it necessary to examine each prospective memory task in only half to sample, thus leading to a great reduction in sample size for each analysis. Therefore, it is possible that the significance level of this finding was hampered by low power. Previous studies employing essentially the same prospective memory task have found significant relationships with measures of working memory (see Kerns, 1998), even after controlling for age. One possibility for the slight discrepancy in findings, aside from low power of analysis, may be the type of working memory task that was used. A previous study (Kerns, 1998) found relationships between the time-based task and visual working memory tasks – the Self Ordered Pointing Task (SOPT) (Petrides & Milner, 1982), and the Delayed Alternation/Non-Alternation Task (Patriot et al., 1996). It has been suggested in the literature that spatial and non-spatial working memory are different entities, reliant on different areas of frontal functioning (e.g. McCarthy et al., 1994; Owen et al., 1996; Petrides, 1995; Petrides, Alivisatos, Evans, & Meyer, 1993). As the time-based prospective memory task did not require primarily spatial abilities, it is probable that a non-spatial task would be more fitting for comparison purposes. If the non-spatial working memory task was more age-appropriate, it is possible that the relationship with time-based prospective memory performance may have been more pronounced. To examine the relationship, in this age range, between this non-spatial working memory task and prospective memory performance, it would be necessary to create an easier version of this task, and to validate it in this age range. However, it is noteworthy that performance on the spatial working memory task was found to be related to an established measure of verbal working memory (Arithmetic); a finding that argues against the working memory distinction hypothesis. Further studies are needed to investigate these differences in working memory tasks, and their relationship to prospective memory performance. Nevertheless, the relationship between working memory and time-based prospective memory found in this study supports the theories set forth in the literature which have suggested similarities between time-based prospective memory and working memory.

A relationship was found between event-based prospective memory (bus) and performance on a visual retrospective memory task. Specifically, relationships were noted with performance on the delayed trial, and also on the four immediate learning trials, although this relationship was no longer significant after controlling for age. Similarities between retrospective memory tasks (especially associative memory tasks) and event-based prospective memory tasks have been noted in the literature (e.g. McDaniel & Einstein, 1993), in that they both require particular information to be associated with a particular event (cue), and for that association to be reinstated at retrieval. The findings of this study lend support to the association between these two systems. There were a few problems with the retrospective memory task used in this study. Firstly, the delay score was necessarily confounded by performance on the learning trials. However, the calculation of a savings score was not sensitive to learning. Therefore, in future studies, the use of a more established task of retrospective cued recall would be warranted.

Importantly, it should be noted at this point that although controlling for age led to non-significant relationships between tasks, the pattern of zero-order correlations suggests that age was not the primary factor driving these relationships. An association (non-significant trend) was found between the time-based prospective memory task and the working memory task, although not between the time-based task and the retrospective memory task. Conversely, a relationship was found between the event-based task and the retrospective memory task, although not between the event-based task and working memory. This dissociation in simple correlations is consistent with the literature and the hypotheses set forth in this study, which predicted a relationship between time-based prospective memory and working memory, and between event-based prospective memory and retrospective memory. Therefore, although all these tasks demonstrated age-related improvement, the pattern of simple correlations suggest that age was not the main contributing factor to the relationships between variables. Thus, it is possible that with a larger sample and more reliable tasks, the relationships between the tasks would have retained significance even after controlling for age.

It has been suggested that the extent to which retrospective and prospective memory tasks are related is in part dependent on the extent that the retrospective component of the prospective memory task contributes to overall performance (Einstein et al., 1992; McDaniel & Einstein, 1993). Therefore in an event-based task with little retrospective memory load (i.e. remembering a simple and undemanding action), correlations may not be found. In this study, the retrospective component of the event-based task was simple, and yet a relationship was still found with the more complex retrospective memory task. However, varying the retrospective memory load in the prospective memory task would be interesting to examine, as this would likely lead to differences in performance, as well as different relationships among tasks.

The recent literature on event-based tasks has suggested some similarities with working memory (Einstein, Smith, McDaniel, & Shaw, 1997; Kidder et al., 1997; Marsh & Hicks, 1998; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Generally, the results suggest that when concurrent working memory task demands are high, they can interfere with event-based prospective memory performance, especially in those with limited working memory resources (i.e. the elderly). It is likely that prospective memory performance requires working memory resources for concurrently holding the ongoing task in mind, keeping the retrieved prospective memory task in mind, sequencing these tasks, and interrupting the ongoing task (Guynn, McDaniel, & Einstein, 1998; McDaniel et al., 1998). Therefore, an intention may be automatically retrieved, but it may be quickly forgotten in the face of competing demands. Working memory demands can increase the likelihood of attentional lapses, particularly if central executive functioning is taxed. Such lapses may be one mechanism that drives prospective forgetting (Kidder et al., 1997). This theory predicts that concurrent working memory load would impair performance on an event-based task, to the extent that the task required self-initiation/self-monitoring. To the degree that a task requires self-initiation and conscious processing, one would expect increased interference when working memory resources are demanded. While time-based tasks usually have these characteristics, it has been shown that event-based tasks can also be affected. Therefore, the creation of event-based task with variable working memory/self-initiation demands would likely result in a different pattern of performance, and would be an interesting area to pursue in future research. Children, like elderly populations, have limited working memory resources, and therefore it would be worthwhile to examine the effects of working memory load on both time-based and event-based prospective memory performance, in a wide age range.

In addition, the literature suggests that a relationship should be observed between working memory and event-based prospective memory, to the extent that the event-based task requires working memory demands. Interestingly, no relationship was found in this study between event-based performance and working memory. There are many reasons why this may have occurred, including low power, ceiling effects on the event-based task, difficulties with the working memory tasks, and widely varied working memory and retrospective memory demands. For example, the cue used in this paradigm was relatively obvious, and thus probably did not place many demands on self-initiated retrieval. In tasks where the cue is not embedded in the ongoing task, but rather part of the background probably increases the amount of self-initiated processing necessary to perform the prospective task (Kidder et al., 1997). Therefore, investigations of the effects of task parameter manipulations will likely be useful, to clarify the nature of the relationship between these memory systems.

Performance on the fragmented pictures paradigm, an implicit memory task, did not show an age effect, which is generally consistent with previous literature (see Parkin, 1993). This task did not correlate with any other memory measure, suggesting the independence of this type of memory from the other memory systems studied. Although similarities have been noted between event-based prospective memory and both indirect and direct retrospective memory tests, no relationships were found in this study. However, it must be noted that this implicit memory task is hampered by low reliability, which reduces the power of analysis (M. E. J. Masson, personal communication, December 1998), and therefore the ability to find correlations. Notwithstanding, while McDaniel et al. (1998) suggested some similarities between event-based prospective memory and indirect memory tasks, the results of their study suggest that prospective memory may be more similar to direct than indirect tests, since dividing attention during a prospective memory task can substantially reduce prospective memory task performance. This effect suggests a process more similar to direct than to indirect tests, which do not involve conscious recollection. However, no relationship was found between the event-based task and the working memory task in this study. One hypothesis for this finding is that the strategic component involved in successful performance of the event-based task, including that which leads to a relationship with direct retrospective memory tasks, appears to involve different processes than those tapped by these working memory paradigms. Alternatively, the relationship between these two variables may not have been large enough to be detected, due to low power of analysis.

Conclusions and Future Directions

This study examined prospective memory in children; specifically the effects of age, type of task, and relationships among tasks were investigated. Due to difficulties with task characteristics (i.e. order effects), conclusions were limited. However, support was found for a developmental relationship of both time-based and event-based prospective memory. In addition the time-based task was found to be more difficult than the event-based task in this study. Refinement of the prospective memory tasks and investigation of the order effects is necessary, to reduce the impact of practice on performance. Also, increasing the age range to include both preschool-age children and adolescents would be interesting. However, the results of this and future studies will likely have utility for the investigation of prospective memory difficulties in clinical populations. For example, children with ADHD are hypothesized to have difficulty with prospective memory, and some preliminary studies have confirmed these hypotheses (Kerns et al. 1998; K. A. Kerns, personal communication, December 1998). Therefore, the knowledge of the normal developmental trajectory of these abilities gained from this and other studies may aid in better elucidating the nature of impairments demonstrated in ADHD and other clinical populations.

A relationship (non-significant trend) was found between time-based prospective memory and working memory, supporting the literature that suggests similarities between these memory systems. The low power of the analysis may have led to reduced significance. Problems were noted with the validity of the working memory tasks. Thus, clarification of the nature of the working memory tasks is necessary, and further investigation into this area is warranted.

A relationship between event-based prospective memory and retrospective cued-recall was found, supporting the similarities between these two memory systems. Recent research into event-based prospective memory has been extensive, and has served to broaden and clarify new areas of investigation. In future studies, the effects of cue characteristics, retrospective load, and working memory load in prospective memory tasks from a developmental perspective would be fruitful to explore.

No relationship was found between an implicit memory task and the other memory tasks, suggesting the independence of this type of memory from the other memory systems studied, although low reliability may have had an effect on these relationships.

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