The Development of Prospective Memory in Typically Developing Children

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Objective: This study aimed to use specifically designed tasks to capture time-based, activity-based, and event-based prospective memory (PM) performance in typically developing school-age children.

Method: Two PM tasks (Fishing Game & Happy Week) were used to examine the developmental patterns of PM in these children. Retrospective memory (RM) was also examined in these tasks. A total of 120 children aged between 7 and 12 years (10 girls and 10 boys in each age band) were recruited. Tests of working memory, inhibition, and IQ were also administered.

Results: The age effect on PM accuracy was significant, with improvements identified between ages 7 to 8 and 10 to 11 years. For both tasks, performance on the time-based PM task was significantly poorer than that on the event-based PM task, which in turn was significantly poorer than that on the activity-based PM task. In terms of errors, results indicated that while errors associated with the PM component of the tasks decreased with age, errors associated with the RM component showed an inverted-U shape. The different patterns of errors suggest qualitative as well as quantitative differences in PM development in children. Finally, IQ, working memory, and inhibition were found to relate to PM when age was partialed out.

Conclusions: Results of the study highlight the importance of contextual cues, such as activities and events, for prospective remembering in children. In addition, they provided a general picture of PM development in school-age children and have implications for educators and parents.

Keywords: prospective memory, children, development

Remembering to implement an intended action in the future is called prospective memory (PM). Common PM tasks in everyday life can be categorized in terms of the nature of the cue triggering them. Remembering to deliver a teacher’s message to parents is a task based on the event of encountering certain people, so called event-based PM. Meeting with friends in a park at 10 a.m. on Sunday morning is a task based on time, that is, time-based PM. Both event- and time-based PM tasks require interruption of activity; in contrast, an activity-based PM task is triggered by the conclusion of an activity, and the cues can be either events (turn off the power of an electronic game console when the game is over) or time (buy gifts at the end of year). Demands on PM increase as children begin their schooling. However, few studies have focused on this age group, which is surprising, given the importance of completing various PM tasks from teachers, parents, and friends and the negative consequences associated with forgetting them.

PM Development

Children have been found to acquire PM ability as early as 2 years of age (Kliegel & Jäger, 2007; Somerville, Wellman, & Cullice, 1983), and to show rapid development of PM after this age (Guajardo & Best, 2000; Kliegel & Jäger, 2007; Kvavilashvili, Messer, & Debdon, 2001; Wang, Kliegel, Liu, & Yang, 2008; Zimmermann & Meier, 2006, for an exception, see Somerville et al., 1983). Meacham (1982) explained this early development of PM as a need to cope within everyday social contexts, and both motivation and incentive rewards have been found to be important factors facilitating prospective remembering in preschool children (Kvavilashvili, Kyle, & Messer, 2007; Somerville et al., 1983).

Relatively less research has been directed to PM in school-age children. Some studies have indicated development in time-based PM in children from age 7 to 12 years (Kerns, 2000; Mackinlay, Kliegel, & Mäntylä, 2009) and one study found significant improvement in event-based PM when comparing 7–8 and 10–11 year olds (Passolunghi, Brandimonte, & Cornoldi, 1995). Negro
and colleagues, however, failed to find any significant development in either time- or event-based PM (Nigro, Senese, Natulio, & Sergi, 2002). Kvavilashvili and her colleague suggested that this discrepant developmental pattern may be due to the trade-off between ongoing and PM tasks. They noticed that improvement in PM in school-age children was modest and nonsignificant when ongoing task difficulty was increased, compared to studies in which it was not. Moreover, meaningful and interesting PM tasks can also reduce the age effect (McGann, Defeyter, Ellis, & Reid, 2005, cited from Kvavilashvili, Kyle, & Messer, 2007). This led Kvavilashvili et al. (2007) to conclude that development of PM is slow in the age range of 7–12 year olds. Their conclusion, however, is contradicted by the findings of a recent study (Mackinlay et al., 2009) that showed significant development in time-based PM, even after the difficulty level of the ongoing task was adjusted. This leaves unclear the developmental pattern of PM in children.

McDaniel and Einstein (2000) have proposed a multiprocess model to explain the complex processes involved in prospective remembering. The model proposes that PM retrieval involves strategic monitoring processes under some conditions (e.g., demanding ongoing tasks, long delays) but relies on automatic processes under others (e.g., salient cues, focal processing of the target events; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Einstein et al., 2005; McDaniel, Guynn,instein, & Brenesir, 2004). In children, the performance of PM tasks can be enhanced when cues are more salient (Kvavilashvili et al., 2001; McGann, Defeyter, Reid, & Ellis, 2007) and are the focus of attention (Maylor, Darby, Logie, Della Sala, & Smith, 2002; Stokes, Pierroutsakos, & Einstein, 2005). In contrast, longer delay requires more strategic monitoring and is detrimental to PM, especially when an additional delay is added between the occurrence of PM cues and execution of the tasks (Rendell, Vella, Kliegel, & Terrett, 2009). These results are consistent with the McDaniel and Einstein model.

PM Tasks

Studies reviewed above indicate that the effect of age on PM is affected greatly by task manipulations and test settings. Thus, in order to capture the development of PM comprehensively, it is important to include more than one PM tasks (Salthehouse, Berish, & Siedlecki, 2004). In developmental PM research, it is difficult to design suitable tests that avoid ceiling effects and at the same time preserve sensitivity to detect subtle developmental changes (Kvavilashvili et al., 2007). Most existing PM tasks for children use a game-like format to stimulate interest as well as maintain attention. One commonly used event-based PM test, named Picture Card, requires children to either name, memorize, or categorize pictures (ongoing task) and hide a particular card (e.g., a specific animal, PM cues) when they encounter it (the PM task; Guajardo & Best, 2000; Kvavilashvili et al., 2001). An example of a time-based PM task is a computerized driving game designed by Kerns (2000). In this game, children use a joystick to control their car so as to avoid other traffic and occasional hazards and their performance is measured both in terms of accuracy and strategy adopted. The goal of the ongoing task is to gain points by avoiding other cars and hazards and the PM task is to refuel the car by pressing a button when the fuel level drops. In another time-based PM task that involved longer delays, children were told to take out cupcakes from an oven or disconnect a battery on charge after 30 min. During the delay, children played an interesting computer game and a clock was placed behind them so that their time-checking behavior could be observed (Ceci & Bronfenbrenner, 1985).

Although these PM tasks were tailored for children, they only included one type of PM task and hence were inadequate for the aim of the present study, that is, to measure and compare different types of PM in one study. Thus, we had to develop comparable PM tasks to delineate the developing processes of different types of PM (i.e., activity-based, event-based, and time-based) in one study. In doing so, we expected to provide a more comprehensive and reliable picture of prospective memory development in children.

Event-, Time-, Activity-Based PM

Performance of event-based PM is expected to be better than time-based PM because the former is cue driven and involves less monitoring and self-initiation (Craik, 1986). Performance of activity-based PM has been found to be significantly better than both event- and time-based PM in normal and clinical participants. This is because activity-based PM does not involve any interruption of the ongoing task and therefore requires less cognitive resources. The differences among the three subtypes of PM are robust and consistent in both healthy and clinic populations (Shum, Ungvay, Tang, & Leung, 2004; Shum, Valentine, & Cutmore, 1999). Nevertheless, the differences in the three types of PM in school-age children remain underinvestigated.

Underlying Neurocognitive Functions

It is important to note that PM develops alongside other neurocognitive functions. Of particular relevance are working memory (WM) and inhibition. General cognitive ability may also play a role in PM tasks. Examining the relationships between PM and these functions may help to explain the development of PM.

WM. This is the ability to hold and actively manipulate information, corresponding to the demands of maintaining PM intention during delay periods and switching from the ongoing task to the PM task when the PM cues are detected. Given that WM develops continuously throughout the early and middle school years (Gathercole, Pickering, Ambridge, & Wearing, 2004), older children should benefit more from their expanding cognitive resources. Cognitive load has also been found to reduce the level of PM performance in children (Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005). The close relationship between WM and PM has been shown mostly in adults (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh & Hicks, 1998; Smith & Bayen, 2005), but the relationship between PM and WM for children aged from 7 to 12 years is less investigated and remains unclear. One study indicated a significant relationship between PM and visual WM after controlling for age (Kerns, 2000). In the other study, the significant relationship between verbal WM and PM disappeared after controlling for ongoing task performance (Mackinlay et al., 2009).

Inhibition. Successful prospective remembering requires interrupting the ongoing task in the right context. This requires the proper functioning of inhibition. In children, this has been dem-
onstrated by the significant correlation between PM and inhibition, after controlling for age (Kerns, 2000) and by the robust effect of interruption on PM performance (Kliegel, Mackinlay, & Jäger, 2008; Kvavilashvili et al., 2001; Wang et al., 2008). Other evidence comes from children with ADHD who have deficits in attention and inhibition, and who also show impairment on time-based PM tasks (Kerns & Price, 2001).

The Present Study

The main purpose of the current study was to examine the developmental trajectory of PM in school-age children between 7 and 12 years of age. This is the age range in which children receive primary school education in China. Two PM tasks were used to delineate a more comprehensive picture of children’s PM development. Although PM development in this group of children is less researched and the developmental trend is inconclusive, improvements in PM with advancing years were expected, given the corresponding development in relevant neurocognitive abilities, the increasing external demands during this developmental period, and the comprehensive and sensitive nature of the PM tasks we employed. The study also examined whether PM performance and its developmental trajectory vary with type of PM cue. Specifically, it was expected that performance of an activity-based PM task would be better than that for an event-based task, which in turn would be better than that for a time-based PM task. Finally, the present study explored the relationships between PM, WM, inhibition, and IQ. All these neurocognitive functions have been considered as potential contributors to age-related changes in PM.

Method

Participants

Children between 7 and 12 years old were recruited from a primary school in Guangzhou, the capital city of the Guangdong province in southern China. The school was selected because of its availability and the willingness of the school administration to be involved. Compared to the other schools in Guangzhou, the selected school is fairly average in terms of educational standard and socioeconomic status of parents. In a pilot study, two children in each age group were recruited to test the feasibility of the two PM tasks. In the main study, 120 children were selected using a random procedure based on a set of seat numbers allocated to all students in the school. This number of participants was mainly based on testing feasibility and it is similar to those used in other cognitive development studies (including PM studies). Equal numbers of boys and girls were recruited and divided into year bands from 7 to 12 (See Table 1). Eight children were excluded from the study because their IQ scores were lower than 75. Eight other students were selected to replace them. All children in the final sample were willing to take part in the study and were able to understand the instructions. The study was approved by the ethics committee of Sun Yat-sen University. Informed consent was obtained from the parents of the children prior to testing.

Prospective Memory Tasks

To measure various types of PM and to increase the validity of assessment, two PM tasks (viz., Fishing Game and Happy Week) were developed for this study. The design of the two tasks followed the basic paradigm developed by Einstein and McDaniel (1990), with PM cues and tasks embedded in an ongoing task. The Fishing Game was a computerized task that involved presenting an animated action game on screen and recording children’s performance based on their operation of the mouse. Happy Week, on the other hand, was a board game that involved advancing from one grid to the next based on the throw of a die. Both PM tasks provided accuracy and error measures for three types of PM, namely, event-, time-, and activity-based. The two tasks were designed to mimic an everyday continuous stimulus environment rather than the artificial consecutive item presentation approach typically used in laboratory-based PM tasks. We expected that these two tasks would add to the scarce number of tasks which have examined the effect of age “in a complex real or virtual environment” (Phillips, Henry, & Martin, 2007).

Fishing Game. The Fishing Game was set in the context of a boy undertaking a fishing competition at a pond. The ongoing task was to hook as many fish as possible to gain points. The points

| Table 1 |

| The Scores of Seven Groups of Children on PM, WM, and IQ Measures |

<table>
<thead>
<tr>
<th></th>
<th>7 (N = 20)</th>
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<th>8 (N = 20)</th>
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<th>9 (N = 20)</th>
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<th>10 (N = 20)</th>
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<th>11 (N = 20)</th>
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<th>Total (N = 120)</th>
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<td>Mean SD</td>
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<tr>
<td>PM</td>
<td>0.35 0.14</td>
<td>0.52 0.17</td>
<td>0.56 0.16</td>
<td>0.57 0.14</td>
<td>0.69 0.14</td>
<td>0.67 0.16</td>
<td>0.56 0.19</td>
<td>0.19 13.434</td>
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<tr>
<td>Fishing Game</td>
<td>1.60 1.39</td>
<td>3.20 1.60</td>
<td>3.30 2.10</td>
<td>3.70 1.78</td>
<td>4.45 2.03</td>
<td>4.80 1.93</td>
<td>3.51 2.07</td>
<td>7.635 &lt;0.001</td>
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<tr>
<td>Happy Week</td>
<td>24.80 9.79</td>
<td>31.95 10.13</td>
<td>34.90 7.72</td>
<td>33.65 5.62</td>
<td>41.48 5.18</td>
<td>37.35 8.95</td>
<td>34.02 9.47</td>
<td>9.497 &lt;0.001</td>
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<tr>
<td>Wrong</td>
<td>0.35 0.81</td>
<td>0.40 0.60</td>
<td>0.40 0.82</td>
<td>0.25 0.91</td>
<td>0.40 0.60</td>
<td>0.30 0.57</td>
<td>0.35 0.72</td>
<td>0.150 0.980</td>
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<tr>
<td>Miss</td>
<td>4.80 1.47</td>
<td>3.80 1.61</td>
<td>3.30 1.84</td>
<td>3.15 1.81</td>
<td>2.10 2.13</td>
<td>2.25 1.77</td>
<td>3.23 1.97</td>
<td>6.334 &lt;0.001</td>
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<tr>
<td>False Alarm</td>
<td>1.40 2.64</td>
<td>2.05 3.03</td>
<td>3.80 7.50</td>
<td>4.25 6.72</td>
<td>2.75 3.71</td>
<td>2.10 2.63</td>
<td>2.73 4.81</td>
<td>1.056 0.389</td>
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<tr>
<td>Repetition</td>
<td>4.10 4.46</td>
<td>7.10 5.71</td>
<td>5.70 5.33</td>
<td>2.80 4.12</td>
<td>2.10 3.65</td>
<td>1.30 1.53</td>
<td>3.85 4.72</td>
<td>5.220 &lt;0.001</td>
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<tr>
<td>IQ</td>
<td>88.73 10.79</td>
<td>94.77 12.11</td>
<td>98.99 12.40</td>
<td>98.86 12.80</td>
<td>98.54 10.43</td>
<td>97.51 15.64</td>
<td>96.23 12.64</td>
<td>2.169 0.063</td>
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<tr>
<td>Two-Back</td>
<td>0.38 0.12</td>
<td>0.42 0.15</td>
<td>0.38 0.11</td>
<td>0.44 0.14</td>
<td>0.57 0.14</td>
<td>0.57 0.15</td>
<td>0.46 0.16</td>
<td>8.225 &lt;0.001</td>
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<tr>
<td>Walk Don’t Walk</td>
<td>0.46 0.21</td>
<td>0.56 0.19</td>
<td>0.61 0.19</td>
<td>0.66 0.17</td>
<td>0.76 0.12</td>
<td>0.67 0.18</td>
<td>0.62 0.20</td>
<td>6.555 &lt;0.001</td>
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Note. PM refers to the PM composite score. Event, time, and activity-based PM scores are calculated by averaging the percentage score of corresponding subtasks of Happy Week Task and Fishing Game. In each age band, there were 10 boys and 10 girls.
gained depended on the size of the fish (see Figure 1). A target score was set up to motivate the children to perform and it increased with age in order to adjust the difficulty level of the ongoing task. The event-based PM task required the children to stop the ongoing task when they saw a middle sized fish with stripes (i.e., the PM cue) and to use the mouse to click on the picture of a cat sitting next to the boy to feed it. The time-based PM task required the children to stop the ongoing task when the digital clock on the upper right corner of the screen reached the full minute (PM cues, e.g., 1 min, 2 min, etc.) and use the mouse to click on the picture of a cat to feed it. To show the children that they had completed the event- or time-based PM task, the mouse click was followed by an animation of the cat eating the fish. The activity-based PM task was scheduled at the end of the fishing competition. It required the children to use the mouse to click on the boat to activate the animation of rowing the fishing boat back to shore when the competition ended. The end of the competition was cued by the appearance of a big fish bone in the middle of the screen (PM cue). To prevent the children from strategically focusing on either the ongoing or PM task, the importance of both tasks was emphasized.

Because frequent appearance of cues could turn a PM task into a monitoring task (Ellis & Kvavilashvili, 2000), three PM cues were scheduled to occur with a 1-min interval for both event- and time-based tasks. In view of children’s limited capacity for sustained attention, both time-based and event-based PM tasks were programmed to last for 3 min 40 s.

For both event- and time-based tasks, PM performance was measured using a number of indices: (a) Correct was the total number of correct responses (i.e., feeding the cat) when the event- and time-based PM cues appeared; (b) Miss was defined as the total number of times children failed to respond when the PM cues appeared; (c) False Alarm was defined as the total number of instances children responded to the wrong cue; and (d) Wrong Response was defined as the total number of wrong actions carried out when the PM cues appeared. The total score of the Fishing Game was calculated by adding all the Correct scores for time-, event-, and activity-based PM tasks. This score ranged from 0 to 8 (number of PM cues for event-, time-, and activity-based PM cues were 3, 3, and 2, respectively). Both Correct and Miss scores for event- and time-based PM ranged from 0 to 3, and for activity-based PM ranged from 0 to 2. For False Alarm and Wrong

![Figure 1. Screen shots of different conditions of Fishing Game.](image-url)
Response, the scores did not have a definite range, because these scores were determined by the number of wrong actions committed by the children during the duration of the PM tasks.

In undertaking the Fishing Game, all children were first introduced to the ongoing task (i.e., the fishing competition) and were given a 1-min practice trial to ensure that they could do the task. Then they received instructions about the PM tasks and were provided with their age-appropriate target score. After that there was a delay period which was filled by the administration of a 5-min cognitive test. The children were not reminded of the instructions of the PM tasks when they began the Fishing Game.

**Happy Week.** This is a board game adapted from Rendell and Craik’s (2000) Virtual Week. The grids of the board were designed to simulate the passage of a day from morning to evening. As shown in Figure 2, in each grid, words and illustrations indicated time, people, or events. To ensure that this task was similar to the children’s daily life, the contents of the grids were chosen based on common school activities reported by a group of 12 children (across the age range of 7 and 12 years old) from the primary school during a short interview.

The main task of Happy Week was to move a toy car to a grid based on the result of a dice throw) and then read aloud the content in that grid. Some grids were embedded with PM cues, and if the children landed on these grids, they had to stop without moving forward and verbally recall the PM task. Each round on the board represented one day and Happy Week consisted of five rounds from Monday to Friday. There were six PM tasks for each day (round). Three were regular PM tasks (e.g., hand in homework) that children were instructed to remember at the beginning of the task. The other three tasks were irregular ones that varied from day to day (e.g., attend art class at 1 p.m. on Wednesday). Regular tasks were those that occurred at a regular interval (e.g., the child has to remember stop at the grid of team lead) and irregular tasks were those that occurred occasionally. Both regular and irregular tasks comprised event-, time-, and activity-based PM, that is, in each day there were two time-based, two event-based and two activity-based PM tasks.

A practice round was always administered to the children to make sure that they understood the rules of the game correctly. At the beginning of each day (round), children were informed about the PM tasks and required to repeat them in order. If they failed to recall correctly, the experimenter repeated the tasks. All children were able to repeat the PM tasks correctly within three reminders by the experimenter. Then a 5-min cognitive test was administered as the delay task. After that the children began their Happy Week “day.”

Regular PM tasks and irregular activity-based PM tasks were simple PM tasks (e.g., having lunch at 12 p.m.), and one point was awarded if a child remembered to stop and correctly recall the task. Irregular event-and time-based PM tasks included extra points for remembering cue, content, and details of the task; for example, feed the rabbit (content) at 4 p.m. (cue) with carrot (details). The total score for Happy Week was 50. The scores for event-, and time-based PM ranged from 0 to 20, and scores for activity-based PM ranged from 0 to 10. For comparison purposes, these scores were converted into percentages. Repetition Error was also recorded for this task because it was noticed during the pilot study that children had a tendency to repeat the tasks that they had already completed on previous days.

**Other Neurocognitive Tasks**

**IQ.** The short version of the Wechsler Intelligence Scale for Children (Chinese adaptation) was used in this study to estimate the children’s IQ (Gong & Cai, 1993). It included four subtests: Bock Design, Picture Completion, Information, and Vocabulary.
According to Goh (1980), the IQ score of this short version correlates highly with the full scale IQ based on the whole test, $r = .95$.

**N-Back Task.** This is a classic working memory task that involves active storage and updating of information. In this study, an N-Back task suitable for children was developed based on an earlier version (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005). It involved three basic figures: triangle, square, and circle. After an 800-ms presentation of a fixation cross, one of the three shapes was presented for 500 ms and followed by a 2000 ms blank, allowing children to respond. There were three subtests, with increasing demands for backward recall. In the Zero-Back subtest, children had to judge whether the figure was a triangle by clicking the left key if yes and the right key if it was not. In the One-Back subtest, they had to judge whether the figure was the same as the previous one. In the Two-Back subtest, they had to judge whether the figure was the same as the one before the previous one. Both accuracy and RT were recorded. Given the ceiling effect in One-Back task for 12-year-olds, only the accuracy of the Two-Back condition was used as the measure in this study.

**Walk Don’t Walk.** This test is part of the Chinese version of the Test of Everyday Attention for Children (TEA-Ch; Chan, Wang, Ye, Leung, & Mok, 2008), which was adapted from the TEA-Ch (Manly et al., 2001). It measures the ability to actively maintain attention and inhibit responses. In this test, children were asked to listen to a tape that played two different sounds which signal either to dot or not dot a square using a maker pen along a path made up of 14 squares. The “to dot” sounds were presented at a regular pace but the “not to dot” sound occurred unpredictably and less frequently. In total, there were 20 paths and the total score was the number of correct responses.

**Procedure**

All children were tested individually in a quiet, well-lit room at the school. They were administered the two PM tasks (Happy Week & Fishing Game) and relevant neurocognitive tests, including IQ, the N-Back Task, and the Walk Don’t Walk task. All children were provided with a small gift at the end of testing. The total time of testing was between 90 to 110 min, depending on the child’s pace and level of performance. Testing was spread into three sessions and all children finished all the tests within a week. To control for practice effects, the event- and time-based PM tasks were counterbalanced for the Fishing Game.

**Results**

**Overall PM Score**

To examine the developmental trajectory of PM in children, a multivariate analysis of variance (MANOVA) was conducted, with the overall PM score as dependent variable and Age and Gender as independent variables. The overall PM score was computed by averaging the total percent correct score of Fishing Game and Happy Week and it ranged from zero to 1. There was a significant Age main effect, $F(10, 216) = 5.934$, $p < .001$, but no significant main effect for Gender, $F(2, 107) = 1.649$, $p = .197$. The two-way interaction between Age and Gender was not significant, $F(10, 216) = 0.889$, $p = .544$. As can be seen from Figure 3, PM performance was at the lowest level in the 7-year-old group ($M = 0.35$), followed by a leap in the 8-year-old group ($p < .001$), and then it stayed roughly the same for the 9 and 10 year old groups. There was another increase in PM performance level in the 11-year-old group ($p = .010$) and this level was maintained for the 12-year-old group. A more delineated developing process can be seen by calculating the effect sizes (ES, Cohen’s $d$) for increment between adjacent age groups: 7–8 (ES = 1.12), 8–9 (ES = 0.25), 9–10 (ES = 0.07), 10–11 (ES = 0.88), and 11–12-year-old (ES = 0.16).

**PM Tasks**

Composite scores for both Fishing Game and Happy Week were calculated by adding up the correct scores of subtasks. There was a moderate relationship between Fishing Game and Happy Week, $r = .38$, $p < .001$. The modest but significant relationship between Fishing Game and Happy Week was also evident in all subtypes of PM: event ($r = .19$, $p = .040$), time ($r = .28$, $p = .002$), and activity-based PM tasks ($r = .22$, $p = .014$). However, the above simple correlation coefficients for the developing children could be inflated by the large age range of the sample. To adjust for this, age was partialled out, and the correlation between Fishing Game and Happy Week diminished but remained significant ($r = .20$, $p = .028$). The significant correlations in subtypes of PM disappeared after controlling for age: event ($r = .11$, $p = .233$), time ($r = .12$, $p = .179$), and activity-based PM tasks ($r = .13$, $p = .175$).

In Happy Week, the correlations among the different PM types were large: time- and event-based PM ($r = .57$, $p < .001$), event-and activity-based PM ($r = .64$, $p < .001$), and time- and event-based PM ($r = .64$, $p < .001$). In contrast, the correlations among different PM types were low in Fishing Game, time- and event-based PM ($r = .13$, $p = .153$), event- and activity-based PM ($r = .13$, $p = .153$), time- and event-based PM ($r = .20$, $p = .014$), and event-and activity-based PM ($r = .20$, $p = .014$).
After controlling for age, the significant correlations remained in Happy Week while the only significant correlation in Fishing Game disappeared.

**Event-, Time-, and Activity-Based PM**

Given the differences in relationships among the three types of PM in Fishing Game and Happy Week, separate analyses were conducted for the two PM tasks. Because the Correct score range varied with PM types, all scores were divided by the maximum total Correct score, resulting in proportion scores ranging from 0 to 1. Repeated-measures analyses of variance (ANOVAs) were conducted with proportion Correct score of three PM types as dependent variable, and Age as independent variable. In Fishing Game, a significant main effect of error type, $F(2, 228) = 42.356, p < .001$, and Age, $F(5, 114) = 7.864, p < .001$, but no interactions, $F(2, 228) = 0.434, p = .929$. Post hoc analysis found the performance on time-based PM was significantly lower than that of event-based PM ($p = .002$), which in turn was significantly lower than that of activity-based PM ($p < .001$). In Happy Week, the results were similar, with a main effect of PM type, $F(2, 228) = 103.021, p < .001$, and Age, $F(5, 114) = 9.281, p < .001$, but no significant interactions, $F(2, 228) = 1.439, p = .164$. Performance on time-based PM was significantly lower than that of event-based PM ($p < .001$), which was significantly lower than that of activity-based PM ($p < .001$).

**PM Errors**

Quite a number of errors were detected in the children’s performance on the PM tasks. In Fishing Game, three types of errors were identified: False Alarm (do PM task when there was no PM cue), Wrong Response (wrong action when PM cue appeared), and Miss (no response to PM cue). In Happy Week, only one type of error was identified, namely, Repetition Error (tendency to repeat what have already been done).

A repeated-measures ANOVA was conducted to examine the three types of Fishing Game errors: False Alarm, Wrong Response, and Miss, with Age as a between-subjects factor. There was a significant main effect of error type, $F(2, 138.20) = 28.868, p < .001$, but a non-significant effect of Age, $F(5, 114) = 1.347, p = .250$. Post hoc analysis indicated that children committed significantly fewer Wrong Responses than False Alarms ($p < .001$) and Misses ($p < .001$), but no significant difference was found between the False Alarm and Miss indices ($p = .964$). A separate repeated-measures ANOVA was conducted to examine the Repetition Error in the Happy Week task, with Age as a between-subjects factor. Repetition Error displayed a dramatic change with age: it peaked at age 8 years and then dropped steeply afterward, $F(5, 114) = 5.220, p < .001$. Post hoc analysis found no significant difference between adjacent age groups for all four types of errors.

According to Zöllig et al. (2007), PM errors can be classified into retrospective memory (RM) and PM components. In the present study, Miss reflected forgetting the initiation of the PM task, a failure of a PM component. In contrast, Wrong Response indicated a weak memory trace for task content, specifically, forgetting the right response to the PM cue; and occurrence of a False Alarm was mainly due to a false memory of PM cues. These latter two types of errors reflected RM component failures and hence were averaged. Repetition Error was also a RM component error, but it was not included in this analysis because it came from a different task (viz., Happy Week). A repeated-measures ANOVA indicated no significant difference between the RM and PM components, $F(1, 114) = 0.093, p = .761$, and there was no interaction with Age, $F(5, 114) = 1.821, p = .114$. Nevertheless, two distinct development patterns were observed (see Figure 5). The PM component error decreased steadily from age 7- to 11-year-old and leveled off at age 12 years. In contrast, the RM component error...
was low at age 7, increased substantially between age 8 to 9 years, slowed at 10 years, and then sharply dropped from age 10 to 11 years, and continued to drop from age 11 to 12 years.

**Relationship Between PM, WM, Inhibition, and IQ**

When age was partialed out (see correlations in parentheses in Table 2), Fishing Game was found to correlate with all neurocognitive functions. Happy Week showed a similar pattern except for the nonsignificant correlation with Two-Back. Among the neurocognitive functions, IQ was found to relate to most PM indices, including PM composite score, both PM tasks, as well as Miss and Repetition errors.

**Discussion**

This study is, to our knowledge, the first to comprehensively investigate the development of various types of PM in primary school-age children. Four major findings are evident from the results. First, PM develops continuously from 7 to 12 years of age, with major leaps in performance between 7 and 8 years and 10 and 11 years. Second, children’s level of performance on the three types of PM task varies but their developmental trajectories are similar. In both PM tasks, children’s performance on the time-based PM task was significantly worse than that on event- and activity-based PM tasks. Third, 8-year-olds made more Repetition Errors compared to other age groups. Fourth, neurocognitive functions assessed in this study (viz., WM, inhibition, and IQ) relate to PM when age is partialed out.

**PM Development in School-Age Children**

The main aim of the present study was to ascertain the developmental trajectory of PM in primary school-age children. We expected large improvement from 7 to 12 years old given increasing external demands for this age range as well as structural and functional changes in the brain during this period. The continuous development of PM ability evidenced in this study confirmed our prediction, which is also consistent with previous findings reported for time-based PM (Kerns, 2000; Mackinlay et al., 2009). From age 7 to 11, PM performance improved linearly and leveled off at age 12, along with errors occurring from time to time. The first major improvement occurred between 7 to 8 years of age, manifesting high frequency of recalling PM tasks and fewer Miss Errors. However, an interesting phenomenon during this period was the remarkable increase in Repetition errors alongside the increment of correct recall, which implies growth in quantity of cognitive resource but not in quality of processing. Eight years old remembered more tasks but tended to repeat what they had done, and this may be because they forgot that they had already finished the task or they confused the recency of PM tasks. From age 8 to 10, growth was slower but accompanied by a steady decrease in Miss errors and a significant reduction in Repetition errors, suggesting qualitative growth. From age 10 to 11, there was another major improvement, with increasing numbers of PM tasks recalled, and the level of PM maintained until age 12. Moreover, the development patterns were similar in all three types of PM (event-, time- and activity-based PM) for both Happy Week and Fishing Game. Particularly, the two major leaps were in accordance with Kerns’ (2000) result in time-based PM for the same age range.

The contrast between PM and RM component errors in Fishing Game indicates different developing processes for the two types of memory (see Figure 5). PM component errors dropped significantly with the two largest drops at age 7 to 8 years and age 10 to 11 years, in accordance with the trend of PM development. In contrast, RM component errors, which might be related to the quality aspect of PM, showed an inverted-U shaped development. Although the ability to remember PM tasks increased dramatically from age 7 to 8 years, the errors of completing PM task increased too. Until 11 years of age, sharp decline in both types of errors marked the maturity of PM skills.

Although the acquisition of PM has been found to start early in life, around age 2 or 3 years (Guajardo & Best, 2000; Kliegel & Jäger, 2007; Rendell et al., 2009; Somerville et al., 1983; Wang et al., 2008; Zimmermann & Meier, 2006), the present study has contributed to this research area by studying older children with a wider age range and by analyzing the nature of errors committed. Combining the development pattern in accuracy with that for errors during the two periods of improvement allows us to delineate the large quantitative change that happens at early childhood and the qualitative transformation that occurs later. The qualitative transformation could be a result of better planning, organization and integration of information, so as to make it more manageable.

**Comparison of PM Tasks**

This study also provided an opportunity to evaluate the utility of two newly developed PM tasks, namely, Happy Week and Fishing Game, for primary school-age children. The Fishing Game and Happy Week were found to be sensitive tools that capture PM development in children from 7 to 12 years old. They can assess event-, time-, and activity-based PM in a comparable context and detect PM errors. Moreover, the PM tasks were well integrated into the task context, that is, they made intuitive sense rather than appeared arbitrary. Specifically, most PM tasks in Happy Week have a high resemblance to the children’s everyday tasks, and they were realistic in reminding children of the consequences in real life. Nevertheless, this high resemblance for children in one culture (viz., Chinese) might limit applicability of the test in another society or country. In this respect, the Fishing Game might be

<table>
<thead>
<tr>
<th></th>
<th>Two-Back</th>
<th>Walk Don’t Walk</th>
<th>IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>0.36 (0.14)</td>
<td>0.36 (0.17)</td>
<td>0.43 (0.38)</td>
</tr>
<tr>
<td>Happy Week</td>
<td>0.28 (0.09)</td>
<td>0.37 (0.22)</td>
<td>0.35 (0.29)</td>
</tr>
<tr>
<td>Fishing Game</td>
<td>0.31 (0.25)</td>
<td>0.25 (0.19)</td>
<td>0.36 (0.30)</td>
</tr>
<tr>
<td>Wrong</td>
<td>0.03 (0.02)</td>
<td>−0.04 (−0.02)</td>
<td>0.08 (0.07)</td>
</tr>
<tr>
<td>Miss</td>
<td>−0.28 (−0.08)</td>
<td>−0.26 (−0.09)</td>
<td>−0.28 (−0.21)</td>
</tr>
<tr>
<td>False Alarm</td>
<td>0.04 (−0.02)</td>
<td>0.05 (0.04)</td>
<td>0.05 (0.04)</td>
</tr>
<tr>
<td>Repetition</td>
<td>−0.19 (0.04)</td>
<td>−0.07 (0.08)</td>
<td>−0.28 (−0.23)</td>
</tr>
</tbody>
</table>

*Note.* Coefficients in bold are significant at 0.05 level (2 tailed), with df = 116. PM stands for the composite score of two PM tasks. Coefficients after controlling the Age are in the parentheses.
considered a better choice for cross-cultural study because it places fewer demands on language in responding and only requires simple operations of a computer mouse. This also makes the task suitable for extending PM research to younger children in the future.

The significant but low correlations between Fishing Game and Happy Week might reflect the differences in nature and complexity of the two tasks. First, the two tasks differed in their output modes. The Fishing Game required motor responses whereas Happy Week required verbal recall. Therefore, children with comparatively late but normal verbal skill development may perform well in Fishing Game but show a lower level of performance in Happy Week. Second, the total composite Correct score in Happy Week takes into consideration detailed recall of intended actions, reflecting both qualitative and quantitative aspects of PM. In contrast, in Fishing Game the composite Correct score only reflects the quantitative aspect, with the qualitative aspect of the task measured by separate error scores. This might also have contributed to the comparatively low correlations between the two tasks.

Relationships Between PM, IQ, Working Memory, and Inhibition

Among neurocognitive functions chosen in this study, IQ showed the most significant correlations with PM indices, implying that general cognitive ability may serve as a basis for planning and successful completion of PM tasks. Inhibition was found to correlate with both PM tasks, suggesting its importance in switching from the ongoing task to PM task, which is consistent with previous findings (Kerns, 2000; Kerns & Price, 2001; Kliegel & Jäger, 2006; Mackinlay et al., 2009). Working memory showed some involvement in the Fishing Game but not in Happy Week, which might be due to the shorter presentation duration of the PM cues in the Fishing Game, which required more monitoring effort, and hence increased the working memory demands.

PM Facilitators

Results of the present study also provided some insights into facilitating factors for PM in children. To our knowledge, children’s performance in all three types of PMs (event-, time- and activity-based) has not been tested together in one study. Research in older adults showed mixed results and was tentatively concluded in a meta-analysis that, for older individuals, performance level on event- and time-based PM is similar (Henry, MacLeod, Phillips, & Crawford, 2004). In the present study, children’s PM performance in both PM tasks was found to vary with type of cue. Compared to the continuously ticking clock in time-based PM, the sudden appearance of cues in event-based PM provided a more salient signal, which required less monitoring and may have helped enhance PM performance (Craik, 1986; Kvavilashvili et al., 2001; McGann et al., 2007). Activity-based PM performance was found to be superior to that for the other two types of PM because it did not require interruption of the ongoing task. Without occupying one’s mind with the ongoing task, initiation of delayed and relevant intention was much easier. Other researchers have also found a similar benefit with children in setting the PM cue at the end of a task (Kvavilashvili et al., 2001; Wang et al., 2008). These results reminded us of the importance of setting appropriate cues to improve children’s successful prospective remembering. For example, event-based PM tasks are preferable, and cues appearing at the end are easier to recall than when they are in the middle of a task.

Some may argue this study did not provide tight control over the task difficulty among the three types of PM cues. For example, activity-based PM cues were more salient than time- and event-based PM cues because the former occurred when the children were not busily engaged in an ongoing task. In fact, the PM task was designed to maximize its resemblance with everyday life tasks, and in most situations, ending of the ongoing task is often accompanied with decrease of attention demand. In both Fishing Game and Happy Week, the presentation duration and styles were similar in three types of PM tasks; hence the difficulty felt in one particular type of PM task in fact reflects its intrinsic nature and is representative of the problem met in everyday life.

This study has a number of limitations that might limit the generalization of the results. First, the findings of the present study were based on a cross-sectional rather than a longitudinal study. Second, it is necessary to bear in mind that our findings provide an approximate description of PM development in a laboratory setting and performance of PM by children in real life situations requires further validation. Third, limited neurocognitive functions were studied; future investigation should consider other relevant functions, such as long term verbal memory, which is often considered as retrospective memory in contrast to prospective memory in the PM literature. Some executive functions, such as switching and initiation can also be included in future research. Fourth, all participants of the study were from the same school with average educational standard, the criteria for inclusion and exclusion were relatively lax, and socioeconomic status was not explicitly measured. Moreover, this study did not examine the strategies that children used in completing the PM tasks, which would be an interesting aspect worth further investigation. Finally, despite an overall big sample, there were only 20 children at each level; therefore, results concerning the jumps from age to age and the increase in RM errors need to be replicated.

In conclusion, the present study used the largest sample to date of school-age children to explore the development of PM. The Fishing Game and Happy Week were found to be sensitive tasks in capturing the development of PM, and they have the potential to become useful tools in studying PM in children. Furthermore, the ecological and game like nature of these tasks might make them suitable in assessing PM in pediatric clinical samples, such as children with head injury or children with ADHD. Before they can be applied in the clinical setting, however, proper test development and norming are necessary. A pattern of continuous growth punctuated by two great leaps in performance between ages 7–8 and ages 10–11 was observed and this pattern was similar across event-, time-, and activity-based PM. IQ, WM, and inhibition were found to have a moderate relationship with PM. Finally, appropriate cues have the potential to benefit children’s PM, which have implications for educators and parents.
References


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