The role of declarative and procedural metamemory in event-based prospective memory in school-aged children

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\textbf{ABSTRACT}

Prospective memory (PM) develops considerably during the primary school years (7 or 8 years of age). Developmental changes have been mainly related to executive functions, although it has been recently suggested that PM would also potentially benefit from metamemory (MM). To date, only procedural MM, operationalized as performance predictions, has been investigated in relation to PM, whereas declarative MM has remained unexplored. Adults’ performance has been shown to improve with predictions, but only in a resource-demanding (i.e., categorical) PM task rather than a more automatic (i.e., specific) one. The aim of the current investigation was to study whether PM performance of 7-year-old children ($N = 59$) would benefit from performance predictions. Thus, half of the children predicted their performance and half of them received standard instructions for two PM tasks: one including categorical PM targets and one including specific ones. To investigate the processes underlying the retrieval of PM targets and the effect of predictions, we obtained measures for declarative MM, inhibitory control, and working memory (WM). Results revealed that children benefitted from performance predictions in the categorical PM task but not in the specific one. This advantage caused slower ongoing task response times, suggesting that strategic monitoring processes were enhanced. Moreover, PM performance was related to WM capacity and declarative MM. However, declarative MM mainly predicted PM advantage in the prediction group, showing that children with high MM knowledge

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benefitted especially from performance predictions. These findings are the first showing the important relation among procedural MM, declarative MM, and PM in school-aged children.

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Introduction

In everyday life, we frequently need to remember to carry out a previously planned action at the appropriate moment (e.g., buying bread when passing by a bakery, taking medicine at 8 a.m., asking a colleague something after a meeting). This ability is defined as prospective memory (PM) (Einstein & McDaniel, 1990), which is crucial for our autonomy and independence in daily life as adults, but especially during childhood and adolescence. For example, PM develops considerably during childhood (Kvavilashvili, Kyle, & Messer, 2008), allowing children to become more and more independent from adult help in daily activities. Particularly when entering school, children are expected to be able to remember (and fulfill) at least some of their self-planned intentions as well as future tasks assigned from others (Mahy, Moses, & Kliegel, 2014). Developmental changes in PM during the primary school years have been shown to be related to development of executive processes (see Mahy & Munakata, 2015). However, recently it has been suggested that PM would also potentially benefit from metamemory (MM), although there is little evidence so far confirming this hypothesis (see Kvavilashvili & Ford, 2014). Our study’s aim was to fill this gap and to investigate the role of both procedural and declarative MM in children’s PM.

Prospective memory in school-aged children and its underlying processes

During the past few years, interest in PM development has increased substantially (see Mahy, Kliegel, & Marcovitch, 2014). Research has shown that PM develops from preschool age, throughout the school years, until late adolescence (Zimmermann & Meier, 2006), with important developmental advances identified between 7 and 8 years of age. In particular, from this age, children have been shown to become increasingly accurate in remembering to execute delayed intentions (Kerns, 2000; Smith, Bayen, & Martin, 2010; Yang, Chan, & Shum, 2011). Besides the importance of retrospective memory (RM) processes for PM development, age-related improvements have been linked mainly to development of executive processes such as inhibitory control, working memory (WM), set shifting, and monitoring (e.g., Spiess, Meier, & Roebers, 2016; Yang et al., 2011).

Mahy, Moses, et al. (2014) proposed an Executive Framework to explain PM development, falling clearly within the developmental research domain and based on the preparatory attention and memory (PAM) theory (Smith, 2003; Smith & Bayen, 2004) and the multiprocess view (McDaniel & Einstein, 2000). Accordingly, developmental advances in executive processes should support PM more particularly, when executive demands of the task are high. Furthermore, the authors claimed that different executive functions would influence PM development at different ages and during different phases of PM (i.e., formation, retention, retrieval, execution, and evaluation of an intention); WM may play an important role during early childhood, whereas inhibitory control, monitoring, and shifting may be crucial later during the school years. Moreover, inhibitory control and set shifting are predicted to influence ongoing task (OT) performance and cue detection, whereas WM and planning would have a greater effect during intention formation and retention. Besides executive processes, the authors also suggested that PM development would benefit from development of MM abilities, which also improve over childhood (especially during the primary school years) and play an important role in RM (see Schneider & Lockl, 2008). However, the study by Kvavilashvili and Ford (2014) remains the only confirmation of this hypothesis in children.
Metamemory and its relation to prospective memory

Metamemory is defined as the verbalizable knowledge and awareness of various memory or memory-related phenomena (Kreutzer, Leonard, Flavell, & Hagen, 1975). It can be distinguished as either declarative or procedural (Flavell & Wellman, 1977). Declarative MM includes all explicit and conscious knowledge and beliefs about memory, whereas procedural MM is related to application of this knowledge, that is, using strategies in addition to controlling, regulating, and monitoring personal memory performances (Flavell & Wellman, 1977). The latter is usually assessed in conjunction with a memory task, before or after which participants are asked to predict or judge their performance (see Schneider, 2015).

Studies on MM development have shown that this increases especially during the primary school years (e.g., Fritz, Howie, & Kleitman, 2010; Schneider, 1986). Whereas age-related improvements in declarative MM are promoted by language development and reasoning ability (Schneider, Kérkel, & Weinert, 1987), advances in procedural MM have been shown to involve monitoring and cognitive control processes (e.g., Isingrini, Perrotin, & Souchay, 2008). MM has been shown to play an essential role in the development of RM (e.g., DeMarie & Ferron, 2003; Geurten, Catale, & Meulemans, 2015). Specifically, at around 7 or 8 years of age, the relation between declarative and procedural MM—that is, MM knowledge and strategy use—becomes stronger and more effective, being increasingly related to children’s memory performance.

Although several studies have investigated the relationship between MM and RM, few have considered the role of MM in PM (e.g., Meeks, Hicks, & Marsh, 2007; Schnitzspahn, Zeintl, Jäger, & Kliegel, 2011). The majority of these have included adults, and only one study has investigated the relation between procedural MM and PM performance in preschool children (Kvavilashvili & Ford, 2014). The authors asked 5-year-old children to predict their performance in both a PM task and an RM task. In line with MM-RM studies (e.g., Fritz et al., 2010), results showed that performance predictions on a memory recall task were generally overestimated and that children were overconfident about their performance. In contrast, when predicting performance on an event-based PM task, children’s forecasts were relatively accurate compared with subsequent achievement. The authors argued that similar processes might underlie performance predictions and PM abilities such as episodic future thinking. In fact, some studies have suggested that projecting oneself into the future, while encoding a prospective intention, can enhance PM performance probably by increasing cue saliency (e.g., Brewer & Marsh, 2010; Kretschmer-Trendowicz, Ellis, & Altgassen, 2016). On the other hand, adults’ outcomes have been rather inconsistent, showing predictions that were not always confirmed by actual PM performance given that adults often underestimated their PM performance (e.g., Meeks et al., 2007; Schnitzspahn et al., 2011). Interestingly, some of these studies have shown that performance predictions improved PM performance (Meier, von Wartburg, Matter, Rothen, & Reber, 2011; Rummel, Kuhlmann, & Touron, 2013). In these, PM performance was higher in a group of participants who needed to make predictions about their PM performance compared with a control group. Moreover, predictions improved performance only on a more resource-demanding PM task (i.e., categorical PM task), but not on a more automatic PM task (i.e., specific PM task). This “prediction” advantage was accompanied by a cost, expressed as slower response times (RTs) on the ongoing task, suggesting that performance predictions enhanced the engagement in strategic monitoring.

The current study

Given the importance of children’s PM abilities when entering school, and the lack of research concerning its various underlying mechanisms (such as MM and executive processes), in the current study we decided to focus on 7-year-old children. This age is supposed to be critical for the development of PM (e.g., Kerns, 2000; Smith et al., 2010; Yang et al., 2011), MM (Schneider, 2015), and executive processes (Anderson, 2002; Lee, Bull, & Ho, 2013) as well as for their relationship (Spiess, Meier, & Roebers, 2015). Moreover, as demonstrated with adults, we were interested in investigating whether performance predictions (namely, procedural MM) would influence children’s performance in a resource-demanding PM task.
In the current study, we manipulated PM task difficulty (within participants) and the presence/absence of PM performance predictions (between participants) in an event-based PM task. Thus, half of the children were asked to predict their performance and the other half received standard instructions before performing two different PM tasks: one categorical (i.e., more resource demanding) and one specific (i.e., more automatic). First of all, children’s performance was expected to be lower in the categorical PM task than in the specific one (Hicks, Marsh, & Cook, 2005). To understand the mechanisms involved in the retrieval of categorical versus specific PM targets more effectively, we further measured individual differences in declarative MM, inhibitory control, and WM. In both tasks, individual differences in WM and declarative MM were expected to predict PM performance. Alternatively, inhibitory control was likely to predict PM performance in the more resource-demanding task as well as OT performance (see Mahy, Moses, et al., 2014).

According to previous studies with adults (Meier et al., 2011; Rummel et al., 2013), performance predictions are expected to improve children’s PM performance by enhancing strategic monitoring processes. This was predicted to have differential impact on the tasks, favoring the categorical PM task rather than the specific one. Furthermore, we were interested in investigating the accuracy of children’s PM predictions and how they might be related to performance in the two PM tasks. Following outcomes of the single previous study with preschoolers, children's performance predictions should be generally accurate with respect to actual PM performance in both tasks (Kvavilashvili & Ford, 2014). In accordance, we would expect that children who predicted they will remember would actually remember to perform the PM task, whereas those who predicted they will forget would actually forget to undertake the PM task. If, in addition to accurate predictions, we also found that predictions benefit PM performance, it would mean that children were able to translate their MM judgments into adequate self-regulation strategies needed to successfully perform the task. This would be evidence that the relation between procedural MM and PM is well developed and that it affects PM performance itself (see Schneider, 2015). Moreover, this pattern of results is more likely to occur on the categorical PM task than on the specific one given that these require different levels of strategic monitoring.

The literature on adult participants, however, indicates that adults are somewhat inaccurate in making predictions and mainly underestimate their PM performance (e.g., Meeks et al., 2007; Schnitzspahn et al., 2011). Accordingly, children who underestimate their future PM performance would probably adopt similar resource allocation strategies, permitting them to perform the PM task correctly. In other words, if children are not completely confident of their performance but are able to perform the task successfully, it is more likely that they would have monitored for the PM targets strategically. If this was the case, although the advantage of making explicit predictions would remain, it would also suggest that children’s strategic monitoring abilities were well developed but, equally, that children were not yet aware of their actual skills. This would be true for the categorical PM task but not the specific one given that strategic monitoring is needed less to perform the latter successfully. Consequently, this would still imply that the two processes are related but that their relation is not yet fully developed. Conversely, if these predictions were incorrect and there was no beneficial effect on PM performance, we could not conclude anything regarding the relationship between procedural MM and PM, and the paradigm would prove to be insufficiently sensitive for our goals.

Method

Participants

A total of 59 children (33 girls and 26 boys) participated in the study; all regularly attended the second grade in the same public school in a city of Northern Italy. Their ages were between 7 years 0 months and 7 years 10 months (mean age = 7 years 5 months), and children were either native Italian speakers or sufficiently fluent in Italian. Parents and children gave written and oral consent, respectively, for participation.
Materials and procedures

Prospective memory paradigm
Event-based PM was measured using the picture classification task, a semi-ecological computerized task based on the classic experimental paradigm proposed by Einstein and McDaniel (1990). The OT consisted of a picture classification task and was created using the SuperLab software. Pictures were real-object photographs taken from the Bank of Standardized Stimuli (BOSS; Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010), with the database consisting of 480 pictures in total. Because the database was standardized with adults, we conducted a preliminary study to adapt the set for 7-year-old children on the bases of familiarity, pleasantness, and category agreement. From the original set, we selected 152 pictures on the basis of high familiarity ($M = 4.24$, $SD = 0.34$, min $= 0$, max $= 5$) and high category agreement ($M = 83\%$, $SD = 14$), subsequently presenting them to a group of 41 7-year-olds attending a public primary school in a city of Northern Italy. Participants were asked to name pictures one by one, evaluating them one for their pleasantness (1 = “I don’t like it,” 2 = “neutral,” 3 = “I like it”) and categorizing them on the basis of five categories represented by the rooms in which they are usually found—kitchen (for food and kitchen utensils), bathroom, kids room (for toys), study room (for school materials), and wardrobe (for clothes). Finally, we chose the most well-known ($M = 98\%$, $SD = 6$), most preferred ($M = 2.49$, $SD = 0.25$), and most easily classifiable ($M = 95\%$, $SD = 6$) pictures to be used in the PM task here. In addition, we calculated mean RTs for picture classification ($M = 5670$ ms, $SD = 1391$) to fix presentation length for each stimulus.

The resulting two versions of the picture classification task consisted of 75 pictures each. One version included three specific PM cues (i.e., a sandwich, a candy, and a ball), whereas the other version comprised three PM cues belonging to a specific category (i.e., fruit). In each picture classification task, participants were required to classify each object on the basis of five categories (kitchen, bathroom, kids room, study room, and wardrobe), which were organized into blocks. Each block was preceded by the name and an image of the category (category pictures were downloaded from the Internet at http://www.midisegni.it/disegni/casa.shtml) following the stimuli in sequence (see Fig. 1 for a schematic example). Stimuli were presented successively on a white background. They remained visible for 5000 ms, being preceded by a fixation cross (500 ms) and followed by a blank screen (250 ms).

Fig. 1. A schematic representation of the ongoing task. At the beginning of each block, the picture and name of the category is presented (e.g., “La cucina”, Italian for “the kitchen”). Afterward, ongoing task stimuli are presented one by one. In the example, a PM cue is included (last picture of the sequence).
Each block consisted of 15 trials, 7 of which were target trials. The three PM cues were embedded in each OT and always were presented on the same position across participants (i.e., every 23 trials).

The task was presented as a game, and instructions were given telling a story, supported by images appearing on the computer screen. Our aim was to make the task as pleasant and ecologically valid as possible, using real-object photographs and reproducing an everyday situation such as tidying the house and packing the backpack for a school trip. Thus, we told a story about a boy named Karl and his dog Bubu. Every time Bubu entered Karl’s house, the dog turned it into chaos and Karl always needed to tidy it up. Karl asked participants to help him put everything in the right place as fast as possible before his mother came back home. To do this, participants needed to respond by pressing the “yes” key (S key) whenever an object was part of the current category and pressing the “no” key (L key) whenever it was not. After a practice trial, the story continued with Karl recounting that he also needed to finish packing his backpack for the school trip and asking for help in finding the missing objects. These objects (PM cues) did not need to be classified by pressing the yes or no key but instead needed to be put into the backpack by pressing the spacebar. Participants were asked to repeat the instructions for the ongoing and PM tasks in their own words, and after ensuring that they understood the procedure, instructions for the filler task were presented. Children were told that Karl needed to finish his homework before tidying up the rooms, and to be faster he asked the participants to help him. The filler task consisted in the spatial reasoning subscale of the Primary Mental Abilities (PMA; Thurstone & Thurstone, 1981; see related sections below) and lasted approximately 5 min. In this instance, participants began the task without repeating the instructions. Participants performed the two versions of the task with an interval of 1 month between the first version (categorical PM task) and the second version (specific PM task). Participants who failed to recognize PM cues were asked the following questions to probe whether failure was due to misunderstanding or inability to remember PM instructions (Kvavilashvili & Ford, 2014): (a) “Was there something else to do during the task besides tidying up the rooms?”; (b) “Was there something else to do whenever specific pictures appeared?”; (c) “Was there something to do when the picture of a fruit appeared?”; and (d) “Didn’t you have to press the spacebar whenever the picture of a fruit appeared?” Participants who were unable to answer the latter question were excluded from analysis because their failure was likely due to forgetting the PM instruction rather than being a pure PM failure (Kvavilashvili et al., 2008).

Procedural metamemory

Procedural MM was evaluated using the same performance prediction paradigm as in Kvavilashvili and Ford (2014). Because this is the only study to have used the paradigm for PM in children, we followed their method to enable comparisons of results. To evaluate the influence of predicting personal performance, we divided our sample into two groups (Meier et al., 2011; Rummel et al., 2013). After giving instructions for the PM task, and after being sure that these were understood, half of our participants were asked whether they thought they would remember the PM task. The following question appeared on the screen and was read to the children by the experimenter: “Do you think you will remember to press the spacebar whenever a fruit appears on the screen in order to put it in Karl’s backpack?” After giving their responses, a confidence rating scale appeared on the computer screen. Participants were asked, “How sure are you that you will remember/forget?” Afterward, they needed to rate their predictions on the scale by pressing either the 1 key (not sure), the 2 key (sure), or the 3 key (very sure). The group of children who needed to predict their performance was the same in the categorical and specific PM task conditions.

Declarative metamemory

In the story task, declarative MM was measured using a modified version of “The Captive Princess” (Cornoldi, Gobbo, & Mazzoni, 1991). A task in a narrative format was chosen in preference to a questionnaire in order to offer children a better opportunity to understand concepts of memory and reflection on mental states (Dyer, Shatz, & Wellman, 2000). The original task was slightly modified to add some MM measures related to prospective remembering. The task is a suitable measure of MM knowledge that has been widely used with preschool- and school-aged children (e.g., Cornoldi et al., 1991; Lecce, Demicheli, Zocchi, & Palladino, 2015). The story is about a prince who wants to save a princess captured in a castle because of witchcraft. Near the castle the prince meets a farmer, who tells him
that, to undo the spell, the prince needs to ask a wise man who lives far away in a cave on the top of a mountain. The farmer also begs the prince to ask the sage to give him medicine for his sick son. The prince promises the farmer to bring him the medicine and departs for his long journey. The first section ends with the prince being in the cave with the wise man, who reveals to him the antidote for the spell (a sequence of actions).

This section comprised three questions: one assessing PM ("Is there something else the prince has to remember to do?") and two others assessing children's knowledge of forgetting ("Do you think the prince remembered to ask for the medicine?" and "The prince didn't remember to ask for it, so why do you think he didn't remember?"). Afterward, children were told that the prince rode the whole way back to the castle. The second section ends with the prince standing in front of the castle's gate, followed by three questions: again two evaluating children's knowledge of forgetting ("Will the prince remember what to do to save the princess?" and "Unfortunately, the prince didn't remember, so why does he not remember?") and one assessing knowledge of retrieval ("What can the prince do in order to recall the antidote?"). At this point of the story, the final section starts and children are told that the prince decides to ride back to the wise man to ask him again what to do to break the witch's spell. Before departing, the prince remembers that he has forgotten to ask the sage for the medicine. Consequently, this third section comprises questions about children's knowledge of storage, that is, knowledge about memory maintenance strategies (e.g., "What can the prince do to be sure to remember to ask for the medicine this time?"). Afterward, the children are told that the prince remembered to ask for the medicine, and after the sage repeats the antidote for the spell to him, they are asked, "What can the prince do to be sure to recall the antidote once he arrives in front of the castle?"

Responses to these questions were coded according to the parameters used by the authors: questions examining knowledge of forgetting were evaluated on a scale of 0 (e.g., "I don't know") to 7 (e.g., "The prince may have forgotten because too much time has passed, during which he had to remember too many things"). The aim of this scale was to evaluate children's knowledge about the decay of information from memory and the sensitivity of information to time delay between coding and retrieval as well as how this time is spent to apply memory strategies. Questions concerning knowledge of retrieval were evaluated on a scale from 0 (e.g., "I don't know") to 5 (e.g., "He has to recover information he used when he learned from the sage what to do"). This measure aimed to examine children's knowledge about rehearsal processes and mental activities able to contrast information's decay from memory. Questions referred to children's knowledge of storage were coded on a scale ranging from 1 (e.g., magic retrieval or simply paying attention to) to 3 (e.g., rehearse information in the head).

Internal consistency of the revised story task was calculated using Cronbach's alpha. The total measure of declarative MM showed good internal consistency, resulting in an overall $\alpha$ of .61.

Verbal and nonverbal abilities

Verbal meaning subscale: Primary Mental abilities. Vocabulary knowledge was assessed using the PMA verbal meaning subscale (Thurstone & Thurstone, 1981). This is a written task, which requires choosing one picture out of four pictures matching the instructions given (e.g., "Mark the apple"). The test consisted of 30 items, and 1 point was given for every correct answer.

Spatial reasoning subscale: Primary Mental abilities. Nonverbal abilities were assessed using the PMA spatial reasoning subscale (Thurstone & Thurstone, 1981). It is a written test with 27 geometrical figures. Each figure needs to be completed with the missing piece, choosing one from four possible options, and 1 point was given for each correct answer.

Verbal working memory

Digit span forward. To measure verbal short-term memory—that is, passive storage—the forward digit span task was used. Children were required to recall verbally presented digits in the same presentation order. Digits were presented at a rate of one per second, starting from the shortest series (three items) and increasing the number of items if the sequence was correctly reported (at least two of the same length). No time limit was given for digit recall, and scoring represented the number of correctly repeated digits.
Digit span backward. Verbal WM—that is, active storage—was measured by means of the backward digit span. This time, children were required to recall verbally presented digits in a reversed order of presentation. As with the previous task, digits were presented at a rate of one item per second, beginning with the shortest series to the longest one (see “Digit Span Forward” section above).

Inhibitory control

To measure children’s ability to inhibit prepotent responses, we used a computerized task based on the Go/No-Go paradigm (see Brocki & Bohlin, 2004). The task consists in the presentation of a series of Go and No-Go stimuli presented randomly in the center of a computer screen. The task requires a response to Go stimuli and its inhibition in response to No-Go stimuli. The task used in this study comprises Go and No-Go stimuli represented by yellow and blue spheres, respectively. These stimuli appeared sequentially in the center of the screen. Each stimulus was preceded by a fixation cross (250 ms) and lasted 500 ms, with a random interstimulus interval ranging from 2550 to 2783 ms (Brocki & Bohlin, 2004). Participants needed to press the spacebar as fast as possible only when the Go stimulus appeared, and they needed to withhold response when a No-Go stimulus appeared. The task consisted of a total of 50 trials, and in order to develop a habitual response the majority of the trials (75%) were Go targets. Performance was evaluated via the number of commission errors (i.e., giving a response to a No-Go stimulus) and omission errors (i.e., failing to respond to a Go stimulus). Commission errors are considered a direct measure of inhibitory control, whereas omission errors represent inattention to the task.

Data analysis

All statistical analyses were performed by means of the free statistical software R (R Core Team, 2016). First, descriptive statistics relating to children’s mean age, gender, and mean scores of the various measures included here have been presented separately for the two groups (i.e., with and without performance predictions). Second, children’s performance predictions were compared with their actual PM performance via ordinal logistic regression. Finally, the effects of performance predictions and the role of WM, declarative MM, and inhibitory control in PM and OT performances were analyzed as follows. A series of four mixed-effects regression models (Pinheiro & Bates, 2000) were run while considering accuracy and RTs of the ongoing and PM tasks as dependent variables. The mixed models fitted on data had the following structure: one dependent variable and several variables included as either fixed or random effects.

Compared with traditional regressions, mixed-effects regressions allow consideration of the whole structure of data in terms of fixed and random effects, thereby ensuring better statistical power. Through this analysis, we could include the same variables of interest as in a common analysis of variance (ANOVA) but also could include several other predictors in the same model of estimation. In the current analysis, we employed mixed models to include group and task as fixed factors and employed other measures (such as declarative MM, WM span forward, WM span backward, and inhibition) that otherwise could have been evaluated in a separate regression model. Moreover, standard regression includes only fixed effects; therefore, it cannot remove part of the variance due to random variables. Mixed models were fit by means of the lme4 package (Bates, Maechler, Bolker, & Walker, 2014).

The two models fitted for accuracy included accuracy for ongoing and PM tasks (one for each model) as dependent variables. Because accuracy for the OT was codified as a dichotomous variable, a generalized mixed model with logit transformation was fit on the data (Jaeger, 2008). The 11 fixed effects considered were group as a two-level factor (Group0 = without predictions and Group1 = with predictions), task as a two-level factor (Task1 = categorical and Task2 = specific), the Group × Task interaction, declarative MM, WM span forward, WM span backward, the inhibition errors in the Go/No-Go task, and the interactions between group and these latter four variables, which were considered as continuous fixed-effects predictors. The random effects considered in the model were the random effect of stimuli (i.e., evaluating the contribution of the various stimuli presented) and participants. These variables were considered as random effects; thus, some sources of data variance were taken into account in the model, and this led to improvement of the statistical power of the analysis. Starting with an initial model including the three effects (group, task, and Group × Task
interaction) and random effects (stimuli and participants), and after ensuring that its convergence was obtained, a forward-fitting procedure was employed (as is typically done with the "glmer" function). Fixed-effects predictors were included in the model one at a time; the predictor was maintained if the model converged, and otherwise it was discarded. The final model emerged after all predictors were tested for significant effect.

The two models fitted for RTs included log-transformed RTs (to reduce data skewness) as dependent variables (for both ongoing and PM tasks by using the correct responses only). In addition to the 11 fixed effects considered for accuracy (group, task, the Group × Task interaction, declarative MM, WM span forward, WM span backward, and inhibition errors in the Go/No-Go task, together with the interactions between group and the latter four variables), trial number (i.e., the ordinal position of each trial within the whole experiment regardless of task type) and the preceding trial (i.e., the RT to the stimulus presented before the current one) were included as covariates. Given that here, the specific PM task was always administered after the categorical PM task, comparison between the two tasks may be affected by practice effects or age-related intellectual maturation. One possible way to disentangle this potential effect is including trial number as a covariate in the analyses, as reported and explained by Cona, Arcara, Tarantino, and Bisiacchi (2012). Finally, a correlation between the observations was taken into account by specifying an additional variable included as an additional predictor; the RTs to the (log-transformed) preceding trial (Baayen & Milin, 2010). The random effects considered were the same used for the two models for accuracy. Each initial model started by including all of the variables, and the automatic backfitting function “step” (lmerTest package version 2.0–33; Kuznetsova, Brockhoff, & Christensen, 2015) was employed. Nonsignificant variables were eliminated from the model one at a time, starting with the variable with the lowest |t| and resulting in a model containing significant effects only.

The four final models yielded by this procedure are shown in Tables 3 and 4 of the Results section. Fixed-effects parameters are interpreted as the effects of traditional regressions. The influence of every fixed effect is calculated, partialing out the influence of the other significant fixed effects. Following standard procedure in regressions, a main effect was kept in the analysis, regardless of its significance, if it was part of a significant interaction.

Results

Descriptive statistics

Descriptive statistics concerning children’s mean age, gender, and mean scores on the various cognitive measures are presented in Table 1. The comparison between the non-prediction and prediction groups was performed through a multivariate analysis of variance (ANOVA): \( F(11, 44) = 0.413, \)

<table>
<thead>
<tr>
<th>Table 1</th>
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<tr>
<td>Means (and standard deviations) of raw scores of the various tests included in this study.</td>
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<tr>
<th></th>
<th>Non-prediction group ( (n = 30) )</th>
<th>Prediction group ( (n = 29) )</th>
<th>Actual range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>7.42 (0.29)</td>
<td>7.32 (0.25)</td>
<td>–</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>M = 13; F = 17</td>
<td>M = 13; F = 16</td>
<td>–</td>
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<tr>
<td><strong>Cognitive measures</strong></td>
<td></td>
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<tr>
<td>PMA verbal abilities</td>
<td>25.93 (1.91)</td>
<td>25.34 (2.26)</td>
<td>0–30</td>
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<tr>
<td>PMA nonverbal abilities</td>
<td>13.93 (4.95)</td>
<td>14.65 (4.63)</td>
<td>0–27</td>
</tr>
<tr>
<td>Inhibitory control (errors)</td>
<td>1.37 (1.07)</td>
<td>1.55 (1.21)</td>
<td>–</td>
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<tr>
<td>Digit span forward</td>
<td>4.40 (0.77)</td>
<td>4.14 (0.74)</td>
<td>–</td>
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<tr>
<td>Digit span backward</td>
<td>2.83 (0.70)</td>
<td>2.76 (0.69)</td>
<td>–</td>
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<tr>
<td><strong>Declarative MM story task</strong></td>
<td></td>
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<tr>
<td>Knowledge of forgetting</td>
<td>8.40 (2.08)</td>
<td>8.24 (1.62)</td>
<td>0–14</td>
</tr>
<tr>
<td>Knowledge of storage</td>
<td>2.67 (1.37)</td>
<td>2.86 (1.38)</td>
<td>0–4</td>
</tr>
<tr>
<td>Knowledge of retrieval</td>
<td>1.57 (1.33)</td>
<td>1.59 (1.21)</td>
<td>0–4</td>
</tr>
<tr>
<td>Declarative MM total</td>
<td>12.63 (3.65)</td>
<td>12.69 (2.95)</td>
<td>0–22</td>
</tr>
</tbody>
</table>

Note. M, male; F, female; PMA, Primary Mental Abilities; MM, metamemory.
Children's data were equivalent and did not show any significant differences in respect of any of the variables: age, \( p = .410, \eta^2_p = .02 \); verbal abilities, \( p = .613, \eta^2_p < .01 \); nonverbal abilities, \( p = .301, \eta^2_p = .02 \); inhibitory control, \( p = .639, \eta^2_p < .01 \); digit span forward, \( p = .363, \eta^2_p = .02 \); digit span backward, \( p = .934, \eta^2_p < .01 \); declarative MM relative to knowledge of forgetting, \( p = .753, \eta^2_p < .01 \); knowledge of storage, \( p = .536, \eta^2_p = .01 \); knowledge of retrieval, \( p = .851, \eta^2_p < .01 \); and total MM score, \( p = .994, \eta^2_p < .01 \).

Performance predictions and prospective memory performance

Of the 59 children, 2 were excluded from the analysis because they failed to remember instructions for the categorical PM task, and 1 was excluded for the same reason for the specific PM task. This indicated that their PM errors were due not to PM difficulties but rather to RM or comprehension difficulties (Kvavilashvili et al., 2008). Of the final sample, 27 children predicted their performance and 29 did not (see Table 2).

Within the PM performance prediction group, in the categorical task, all of the children predicted remembering the PM task; of these, 12 were “sure” and 15 were “very sure” to remember. Of these 27 children, 21 (78%) remembered the PM task effectively, indicating that children are able to predict their actual performance with reasonable accuracy. An ordinal logistic regression was performed on the group with prediction only, with the two variables confidence (as predictor, values of “sure” and “very sure”) and remembered (as predicted, range of 0–3). Results indicated a value of −0.500 (SE = 0.709), with \( t = −0.705 \) (ns). This shows that for the categorical task, although children are able to predict the direction of their performance, their precision is not indicative.

Within the specific PM performance task, 26 children in the prediction group predicted remembering, with 1 child predicting he would forget. In this instance, 21 of 27 made a congruent prediction (82%), remembering (or not) the PM task effectively. The ordinal logistic regression showed a value of −2.638 (SE = 1.154), with \( t = −2.286 \) (\( p < .05 \)). This indicates that for each unit increase in confidence (e.g., passing from “sure” to “very sure”), we would expect an approximately 2.5-unit decrease in the expected value of items remembered in the log odds scale. That is, the most optimistic children performed worse than those who were more conservative in predicting their performance.

Effects of performance predictions on the prospective memory and ongoing task performance.

Ongoing task performance

For the OT (Table 3), accuracy did not differ across groups or tasks (see Fig. 2A). The only significant predictor resulted from the covariate inhibition error; for high values of this variable, OT accuracy was low. All other predictors were introduced one by one, but the model failed to converge for all of them.

Response times for the OT were slower for the group with predictions, compared with the group without predictions, but in the categorical task only (see Fig. 2B). Moreover, a significant effect of the preceding trial was found (and removed from the main effect across both tasks) given the high correlation of the latency of current trial with that of the preceding trial (Baayen & Milin, 2010). The significance of random effects for stimuli and participants indicates significant variability in the overall performance of each participant and among the various stimuli. Moreover, it indicates that, taking these sources of variance into account, the goodness of fit of the model improves (the effect size of

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence judgments of performance predictions related to the number of remembered cues in the categorical and specific prospective memory tasks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task</th>
<th>Confidence</th>
<th>Total</th>
<th>Remembered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Categorical</td>
<td>Sure</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Very sure</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Specific</td>
<td>Sure</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Very sure</td>
<td>16</td>
<td>5</td>
</tr>
</tbody>
</table>
Importantly, because the four variables of inhibition error, declarative MM, WM span forward, and WM span backward were excluded during the backfitting procedure, they should not be considered as relevant predictors in the analysis presented.

### Table 3
Mixed-effects regression model for ongoing task performances.

<table>
<thead>
<tr>
<th>Fixed-effect parameter</th>
<th>Accuracy</th>
<th>Reaction time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta (SE) )</td>
<td>( z )</td>
</tr>
<tr>
<td>Intercept, Group0, Task1</td>
<td>2.953 (0.138)</td>
<td>21.37</td>
</tr>
<tr>
<td>Group1 = with predictions</td>
<td>0.187 (0.159)</td>
<td>1.17</td>
</tr>
<tr>
<td>Task2 = specific</td>
<td>0.150 (0.129)</td>
<td>1.15</td>
</tr>
<tr>
<td>Group1 ( \times ) Task2</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Inhibition Errors</td>
<td>–0.171 (0.058)</td>
<td>–2.95</td>
</tr>
<tr>
<td>Log(Preceding Trial)</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Random-effect parameter</td>
<td>SD</td>
<td>SD</td>
</tr>
</tbody>
</table>

### Table 4
Mixed-effects regression model for prospective memory performances.

<table>
<thead>
<tr>
<th>Fixed-effect parameter</th>
<th>Accuracy</th>
<th>Response time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta (SE) )</td>
<td>( Z )</td>
</tr>
<tr>
<td>Intercept, Group0, Task1</td>
<td>–16.512 (4.682)</td>
<td>–3.526</td>
</tr>
<tr>
<td>Group1 = with predictions</td>
<td>4.092 (1.068)</td>
<td>3.831</td>
</tr>
<tr>
<td>Task2 = specific</td>
<td>3.631 (2.080)</td>
<td>1.746</td>
</tr>
<tr>
<td>Group1 ( \times ) Task2</td>
<td>–5.049 (1.130)</td>
<td>–4.468</td>
</tr>
<tr>
<td>Declarative MM</td>
<td>0.332 (0.137)</td>
<td>2.414</td>
</tr>
<tr>
<td>WM Span Forward</td>
<td>1.504 (0.682)</td>
<td>2.204</td>
</tr>
<tr>
<td>Group1 ( \times ) Declarative MM</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Random-effect parameter</td>
<td>SD</td>
<td>SD</td>
</tr>
<tr>
<td>Random-effect Participants</td>
<td>2.651</td>
<td>0.133</td>
</tr>
</tbody>
</table>

Note. The model for accuracy was computed using all responses (correct and incorrect) through this formula: \( \text{glmer}(\text{accuracy} \sim \text{group} + \text{task} + \text{InhibitionErrors} + (1 \mid \text{Participants}), \text{data} = \text{ongoing_accuracies}, \text{family} = \text{"binomial"}) \). The model for reaction times was computed using the correct responses only through this formula: \( \text{lmer}(\log(\text{ongoing_RTs}) \sim \text{group} \cdot \text{task} + \log(\text{Preceding Trial}) + (1 \mid \text{Stimuli}) + (1 \mid \text{Participant}), \text{data} = \text{ongoing_RTs}) \). MM, metamemory; WM, working memory.

The model is \( r^2 = .27 \). Importantly, because the four variables of inhibition error, declarative MM, WM span forward, and WM span backward were excluded during the backfitting procedure, they should not be considered as relevant predictors in the analysis presented.

### Prospective memory performance

Considering PM (see Table 4), analyses on accuracies revealed that the interaction between task and group was significant. When PM cues were categorical, children who predicted their performance were more accurate than children who did not, whereas there were no differences between the groups when PM cues were specific (see Fig. 3A). Moreover, a significant contribution of declarative MM and WM span forward was found. Both measures were direct predictors of the accuracy for PM trials, so that the higher these values were, the higher the accuracy for PM trials was.

Response times for the PM tasks were slower for the group without predictions compared with the group with predictions (see Fig. 3B); both groups also differed with respect to declarative MM.
A nonsignificant main effect of declarative MM and the significant interaction of Group1 × Declarative MM indicate that metamemory knowledge was a significant predictor for the performance prediction group only. In this group, higher declarative MM scores were associated with faster RTs. The predictor variables of inhibition error, WM span forward, WM span backward, and their interaction with group were excluded during the backfitting procedure. This suggests that these predictors were not able to account for variability in RTs. The effect size for this model was $r^2 = .52$.

**Effects of confidence judgment of predictions on prospective memory performance**

To evaluate the effects of differential prediction precision, a further analysis added the factor prediction confidence (1 = “very sure” and 2 = “sure”) to the models previously used by including participants with predictions only. Analyses were conducted separately for each task given that a prediction could be reliably connected to the current task but not to both tasks. Results indicated that, in the categorical condition, models for RTs converged for the OT only (intercept, Pred1 = “very sure”: $\beta = 7.334, SE = 0.173, t = 42.49, p < .001$; Pred2 = “sure”: $\beta = 0.121, SE = 0.035, t = 3.43, p < .01$; Log(preceding trial): $\beta = 0.046, SE = 0.022, t = 2.07, p < .05$), suggesting that participants who predicted “sure” showed slower RTs than those who predicted “very sure.”

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**Fig. 2.** OT performances including either categorical or specific cues represented by mean proportion (A) and RTs (B) of correct responses for the non-prediction and prediction groups. In Panel A, error bars represent 1 standard error, whereas points represent the values for participants. In Panel B, upper and lower limits of the boxes represent the 25th and 75th quartiles, whereas the central line represents the median; the two whiskers sticking out of the top and bottom of the box extend to 1.5 times the interquartile range. The black dot represents the mean value, whereas the gray dots indicate the RTs.

**Fig. 3.** PM performances including either categorical or specific cues represented by mean proportion (A) and RTs (B) of correct responses for the non-prediction and prediction groups. In Panel A, error bars represent 1 standard error, whereas points represent the values for participants. In Panel B, upper and lower limits of the boxes represent the 25th and 75th quartiles, whereas the central line represents the median; the two whiskers sticking out of the top and bottom of the box extend to 1.5 times the interquartile range. The black dot represents the mean value, whereas the gray dots indicate the RTs.
In the specific condition, the models converged for PM accuracy (intercept, Pred1 = “very sure”: $\beta = -13.35$, $SE = 5.12$, $z = -2.61$, $p < .01$; Pred2 = “sure”: $\beta = 6.86$, $SE = 2.56$, $z = 2.69$, $p < .01$), showing that participants who predicted “sure” showed higher accuracy rates than those who predicted “very sure.” This also occurred for RTs (intercept, Pred1 = “very sure”: $\beta = 7.74$, $SE = 0.29$, $t = 26.64$, $p < .001$; Pred2 = “sure”: $\beta = -1.29$, $SE = 0.56$, $t = -2.28$, $p < .05$; declarative MM: $\beta = -0.03$, $SE = 0.014$, $t = -2.34$, $p < .05$; inhibition errors: $\beta = 0.143$, $SE = 0.037$, $t = 3.90$, $p < .001$; Pred2 = “sure” × Declarative MM: $\beta = 0.046$, $SE = 0.022$, $t = 2.09$, $p < .05$). This shows that RTs for participants who predicted “sure” were faster than for those who were “very sure” of their prediction, and the interaction indicated that the latter group (“very sure”) was faster with higher declarative MM, whereas the former group had no impact of declarative MM. In addition, a general effect of inhibition errors was also reported, indicating that a higher number of errors led to slower RTs in both groups.

Discussion

The aim of the current investigation was to study the relationship between MM and PM in 7-year-old children. First, we were interested in examining whether children’s PM performance would benefit from procedural MM operationalized as performance predictions. Thus, half of our participants were asked to predict their performance and half received standard instructions for two different PM tasks: one being more resource demanding (i.e., categorical PM task) and one being less resource demanding (i.e., specific PM task). Moreover, we were interested in evaluating children’s accuracy in predicting their PM performance in the two different tasks. Finally, to investigate the processes underlying the retrieval of different PM tasks and the effect of predictions, we also evaluated inhibitory control, WM, and declarative MM.

Consistent with previous studies (e.g., Hicks et al., 2005), our results showed that accuracy was generally lower in the categorical PM task than in the specific one, indicating that responding to a categorical PM task is more resource demanding than responding to a specific PM task. In both tasks, inhibitory control abilities predicted accuracy in the OT, supporting the Executive Framework of PM development (Mahy, Moses, et al., 2014). However, contrary to what we expected, inhibitory control was not implicated in PM target detection. That said, accuracy in both PM tasks (but not RTs) was related to WM capacity (i.e., consistent with Smith & Bayen, 2005, and Yang et al., 2011). Thus, as predicted by the Executive Framework (Mahy, Moses, et al., 2014), children with greater WM span also had higher PM accuracy. An interesting and new finding was that declarative MM was an important predictor of PM performance as well, showing that children with higher MM knowledge were better at prospective remembering. So far, the link among declarative MM, strategy use, and memory performance has been investigated only in relation to RM. These studies have shown that relation between these processes becomes stronger at around 7 years of age and is linked to advances in executive functions (see Roebbers & Feurer, 2016).

With respect to PM, to date only procedural MM has been considered using the performance prediction paradigm (e.g., Meeks et al., 2007; Schnitzspahn et al., 2011). Recent studies have also investigated the direct effect of predictions on adults’ PM performance by comparing groups with and without performance predictions (Meier et al., 2011; Rummel et al., 2013). Our results replicated these findings, showing that even 7-year-old children can benefit from performance predictions. Moreover, as in the adult studies, making predictions improved children’s PM performance in the categorical PM task but not in the specific one when compared with the non-prediction group. This PM advantage was accompanied by slower OT RTs, indicating that these children monitored strategically for detection of PM targets (Smith, 2003; Smith & Bayen, 2004). Moreover, the prediction group was faster than the non-prediction group in detecting the PM targets, further indicating that the former group monitored strategically in detecting categorical PM targets. Interestingly, faster RTs to PM targets in the prediction group were mediated by declarative MM. Specifically, those children in the prediction group with high declarative MM were also those who monitored strategically the most for PM targets.

To investigate how the effect of performance predictions might be related to performance in both PM tasks, we further analyzed children’s PM prediction accuracy (i.e., procedural MM). Similar to Kvavilashvili and Ford’s (2014) study with preschoolers, the percentage of children who predicted
remembering and actually remembered the PM task was relatively high (>70%), showing that they were able to predict the direction of their future performance. However, when considering confidence judgments of predictions, precision was not always optimal. In the categorical PM task children's confidence judgments were not directly related to actual PM performance, whereas in the specific PM task they were. Children who showed some caution (i.e., were only “sure” of their prediction) were more accurate and faster in detecting specific PM cues than children who were “very sure” of their prediction. Again, this indicates that they may have monitored strategically for detection of PM cues. However, given that successfully performing a specific PM task relies more on automatic and spontaneous processes, it follows that engaging in strategic monitoring is not functional (Einstein et al., 2005). That said, in the categorical PM task, confidence judgments were related to OT RTs. Similarly to the specific condition, less overconfident children also had slower RTs, suggesting that they monitored strategically for detection of categorical targets. These children may have judged the task as being more difficult, which resulted in a change of attention allocation policies, as argued by Hicks et al. (2005; see also Rummel & Meiser, 2013). Although reasonable, this interpretation needs to be corroborated further.

Studies using the performance prediction paradigm in relation to RM have frequently revealed inconsistent results (see Schneider, 2015), and adults’ predictions also have not always been accurate, compared with their PM performance (e.g., Meeks et al., 2007; Rummel et al., 2013; Schnitzspahn et al., 2011). However, in Ksavishvili and Ford’s (2014) study, 5-year-old children seemed to be highly accurate in their PM predictions. Some researchers have argued that making accurate predictions may be influenced by a variety of factors (e.g., motivation, task familiarity, mode of assessment or training)—factors that seem to be independent of metacognitive development. For example, Schneider (1998) reported that children often respond inconsistently when they need to predict performance, especially when a task is unfamiliar. Consequently, their predictions are not necessarily related to metacognitive deficits but rather are related to motivational factors such as wishful thinking. The majority of children in our study (100% in the categorical condition and 93% in the specific condition) predicted they would remember the task, indicating that they may have been highly motivated to succeed. This may have increased not only children’s motivation but also their perception of importance of the PM task, in turn boosting their cognitive resources in order to detect the PM targets correctly (i.e., engaging in strategic monitoring similar to that described above). Similarly, manipulating the importance of the PM task has been shown to increase monitoring and improve PM cue detection while interfering with the OT performance (see Walter & Meier, 2014, for a review).

However, the fact that in the current study nearly all participants stated that they would remember rather than forget the PM task may represent a limitation. Future studies should attempt to balance evaluations, providing comparable numbers of children who predict to remember or forget. It would be reasonable to use more confidence levels as well as to use different question types to the yes/no format. This would make it possible to compare PM performance between children who predicted successful performance and those who predicted the reverse, giving us better insight into children’s procedural MM in relation to PM. However, we suggest that delayed predictions and “post-dictions” (i.e., evaluations of one’s own performance while performing and after having performed the task, respectively; see Schneider, 2015), may be better indicators of procedural MM. Indeed, task experience may enhance participants’ insight into their likelihood of successful task performance, thereby increasing precision. Alternatively, immediate performance predictions might not be a pure procedural MM measure given that they are likely to be distorted by other factors, as seen in both the current study and previous studies with adults (Meier et al., 2011; Rummel et al., 2013).

Besides the similar patterns of our results and the adult literature, one may question whether the differences between categorical and specific tasks were due to their sequence of administration given that this variable was not counterbalanced. The mixed-effects model approach was adopted to eliminate confounding factors from the main effect; however, during the 30 days’ interval between the first and second administrations, children may have developed cognitively, thereby attaining better performance. Our data seemed to contradict this critique given that it is unlikely that development occurred in the non-prediction group only. Moreover, other results were not affected by this potential confound given that various effects (e.g., WM, declarative MM, inhibitory control) were found in both categorical and specific tasks. Another critical point can be represented by accuracy rates on the
specific PM task, which were high and nearly at ceiling. To clarify these points, a similar study has recently been conducted (Cottini, Basso, & Palladino, in preparation) in which 7-year-old children performed a comparable OT but with specific PM cues only. In that study, task difficulty was higher given that five PM targets were included instead of the three used in the current study. In the same way, only half of the children were asked to predict their performance. Preliminary results seem to corroborate our data, showing that performance predictions did not influence children’s performance on a specific and more automatic PM task.

Summary and conclusions

The evidence emerging from our study is the first to demonstrate that performance predictions can be used with school-aged children as an effective strategy to improve performance on cognitively demanding PM tasks. To our knowledge, it is also the first study to explore the relationship among PM, declarative MM, and executive processes in school-aged children. Declarative MM has been shown to play an important role not only in the ability to remember to perform an intention but also in the engagement of strategic monitoring processes. Because WM is another important factor for successful prospective remembering, in future research it would be interesting to explore the effect of interventions on these two processes. Unlike the effect of training on cognitive processes, which may be time and resource demanding for children and which might not always show transfer effects, providing simple strategies (such as thinking of possible future performance) may be effective in enhancing PM abilities. Similarly, this was shown in a study including older adults who benefitted substantially from an implementation intention strategy, in contrast to cognitive processing training (Brom & Kliegel, 2014). In future studies, it would be useful to compare the effects of different strategies that can be used during intention formation for different PM tasks. Strategies such as implementation intentions (e.g., Basso & Olivetti Belardinelli, 2006; Gollwitzer, 1999) and episodic future thinking (e.g., Brewer & Marsh, 2010; Kretschmer-Trendowicz et al., 2016) may be useful in more automatic PM tasks because they seem to strengthen cue–action association. Alternatively, emphasizing PM task importance or making performance predictions can be used in more resource-demanding PM tasks. It also would be informative to study the processes underlying the effect of various strategies on different PM tasks. Future research should also include different age groups as well as clinical populations with PM difficulties such as children with autism spectrum disorder (e.g., Henry et al., 2014) and attention deficit/hyperactivity disorder (e.g., Kliegel, Ropeter, & Mackinlay, 2006). Because executive and metacognitive processes in those populations are often insufficient, it may be useful to see whether these children’s PM would benefit from performance predictions or other strategies.

In conclusion, the current study allowed us to define the contribution of explicit performance prediction, which indicated a positive effect on a resource-demanding PM task, as well as important roles of declarative MM and WM. This evidence may, in turn, allow us to determine the most important factors in implementing pragmatic educational procedures. Moreover, the current study may encourage future research to study development of PM in relation to declarative and procedural MM.

Acknowledgments

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References


