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PhD Thesis:

INVESTIGATING THE ROLE OF METAMEMORY IN PROSPECTIVE MEMORY OF SCHOOL-AGED CHILDREN

by

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Declaration

This dissertation is a cumulative work including the following papers:

Paper 1 (Chapter 5): Cottini, M., Basso, D., & Palladino, P. (2018). The role of declarative and procedural metamemory in event-based prospective memory in school-aged children. *Journal of Experimental Child Psychology*, *166*, 17–33.

Paper 2 (Chapter 6): Cottini, M., Basso, D., & Palladino, P. (submitted for publication). *Performance predictions and evaluations in prospective memory in school-aged children.*

Paper 3 (Chapter 7): Cottini, M., Basso, D., & Palladino, P. (in preparation). *The longitudinal development of prospective memory and metamemory in school-aged children.*

Table of Contents

List of Figures and Tables

Abstract

Prospective memory (PM) develops considerably during childhood and especially around 7 and 8 years of age. Developmental advances in PM during this age period have been primarily linked to executive functions (EFs), such as inhibitory control, set shifting, working memory (WM) and monitoring. However, recently it has been suggested that also metamemory (MM) would be potentially involved. To date, only few studies have investigated the relation between MM and PM. The aim of the present work was to investigate the effect and the role of procedural MM in PM of 7- and 8-year-old children by using different methods (i.e., performance predictions, postdictions, and self-reports concerning strategy-use). Moreover, the role of declarative MM as well as EFs has been examined. In Study 1 we investigated whether and how children's PM performance on two different tasks (categorical vs. specific) would benefit from making performance predictions. Results replicated findings with adults, showing that, although not accurate, performance predictions improved performance on a categorical and more resource-demanding PM task but not on a specific and more automatic PM task. This prediction-advantage was associated to an ongoing task (OT) performance slowing, suggesting that strategic monitoring processes were enhanced. Both declarative MM and WM significantly contributed to overall PM performance. In Study 2, we adopted a prediction-postdiction paradigm to evaluate children's performance judgments before and after performing a specific PM task. In addition, children were asked whether and which strategy they used to perform the task. While performance predictions were not related to and had no effect on subsequent PM performance, replicating previous studies, postdictions were quite accurate. Moreover, strategy-use resulted to be the main predictor of children's PM performance, showing that using an active strategy not only supported successful retrieval of the PM task, but also enhanced monitoring processes. Finally, Study 3 examined longitudinal relationships between MM, PM and EFs in children at the age of 7 and 8 years. The same experimental procedure of Study 1, including only the categorical PM task, has been adopted. Results showed that children's performance improved on all measures after one year. However, the effect of performance predictions on PM performance disappeared. PM improvements at Time 2 could not be explained by any of the included variables except for PM performance at Time 1. Taken together, these experiments are the first exploring and revealing the important relationship between MM and PM in school-aged children by using different methods such as performance predictions, postdictions and self-reports related to strategy-use. Theoretical and methodological implications emerging from these experiments as well as the importance of considering MM aspects when studying PM in children will be discussed.

Introduction

The ability to remember to perform a previously planned intention in a specific moment in the future is defined as *prospective memory* (PM; Einstein & McDaniel, 1990). PM is used in various everyday life situations, such as remembering to send a letter when passing by the post office (i.e., event-based), feeding our pet (i.e., habitual), paying a fine in time (i.e., time-based), or making a phone call after a meeting (i.e., activity-based). PM is an essential ability for the successful attainment of daily goals, across the entire lifespan, and in different settings (e.g., school, academics, work, family, social relationships, heath and wellbeing).

PM becomes important especially when entering school. Whereas preschoolers are supported by adults, school-aged children are expected to remember to perform at least some of their personal goals or assignments obtained from others (see Mahy, Moses, & Kliegel, 2014a). Indeed, PM develops considerably during the primary school years, and particularly around the age of 7 and 8 years (Kerns, 2000; Smith, Bayen, & Martin, 2010; Yang, Chan, & Shum, 2011). Executive functions (EFs) were found to be the major driving forces of these developmental changes (see Mahy, Moses et al., 2014a; see Mahy & Munakata, 2015). However, developmental research has often neglected an important aspect potentially related to both PM and EFs, namely metamemory (MM; Kvavilashvili & Ford, 2014; Spiess, Meier, & Roebers, 2015). To date, only few studies have investigated the relation between procedural MM and PM by using the performance prediction paradigm (e.g., Meeks, Hicks, & Marsh, 2007; Schnitzspahn, Zeintl, Jäger, & Kliegel, 2011), and only one of them included children (Kvavilashvili & Ford, 2014). The purpose of the present work was to fill this gap and to examine the role of both procedural and declarative MM in event-based PM in school-aged children by including different measures of MM. Consequently, the different experiments conducted for this dissertation aimed at defining a valuable methodology for the investigation of MM and PM in children as well as increasing the knowledge about the processes underlying PM development during childhood.

Chapter 1 will give a theoretical overview describing characteristics, processes, and models concerning the concept of PM. Chapter 2 will provide a summary of the literature on PM development with a special focus on the primary school years. Age-related advances in PM and their link to EFs will be discussed. After providing a brief theoretical overview of MM, Chapter 4 will concentrate on the development of its components during childhood (i.e., procedural and declarative MM). Finally, a review of the MM-PM literature will be included. Subsequently, the empirical section of the present work will be introduced. This part will include different studies examining the role of procedural and declarative MM as well as of EF in PM of school-aged children. Chapter 5 will describe the first study aimed at investigating the effects of performance predictions (i.e., procedural metamemory) on PM performance in different tasks, as well as the role of declarative MM and EFs. Chapter 6 will present a further study focusing mainly on the role of procedural MM on PM performance, by using different measures for procedural MM. Chapter 7 will include a third study examining the longitudinal development of the relation between PM, MM and EFs, by adopting in part the experimental design of the first study. In Chapter 8, the principal outcomes of the empirical studies will be summarized and discussed. Furthermore, theoretical and methodological implications as well as directions for future research will be presented.

1. Prospective Memory

1.1. Definition of Prospective Memory and Importance in Everyday Life

PM is defined as the ability to remember to execute previously planned actions at specific moments in the future (Einstein & McDaniel, 1990). For instance, remembering to buy bread when passing by the bakery (i.e., event-based), paying a fine in time (i.e., time-based), taking medicine between meals (i.e., habitual) or asking something to a colleague after a lesson (i.e., activity-based), are all different everyday situations in which PM is involved. In the present work we will exclusively refer to event-based PM, namely PM tasks in which the intention is associated to an external *cue*.

Typically PM tasks are characterized by a delay period between the formation and the execution of an intention, the absence of an explicit prompt which reminds us the intention, and the necessity to interrupt ongoing thoughts or activities to realize it (Ellis & Kvavilashvili, 2000). Consequently, an important characteristic of PM tasks is that intentions have to be performed while we are engaged in other ongoing activities, like for example, stopping a conversation on the phone when passing by the bakery to buy bread. Successfully performing a previously planned action heavily depends on remembering the content of an intention, that is, *what* to do and *when* to do it, as well as on remembering to execute it in the right moment. Consequently, PM can be divided in two components (Einstein & McDaniel, 1990): a retrospective component, relying on retrospective memory (RM) processes (i.e., remembering the content of the intention); and a prospective component, relying on executive processes (i.e., remembering to execute the intended action at the appropriate moment).

1.2. Differences between Prospective and Retrospective Memory

RM refers to the ability to remember past events and information, like for example details about our last vacation, the capital city of a specific country, or how to cook pasta. Although RM plays an important role in PM, the two processes are clearly distinct (see Einstein & McDaniel, 1990): 1) First of all, the *retrieval* process in PM is mainly self-initiated, without having explicit external prompts. Remembering to perform a previously planned action at the right moment requires us to identify autonomously the appropriate context or reminders, and to initiate a strategic search in memory to retrieve the associated action. On the contrary, retrieval of past events is generally externally cued and explicitly prompted (e.g., being asked the title of the last book we read). 2) Subsequently, performing a future intention is more difficult, since the retrieval of our intention typically requires us to interrupt our thought flow while we are engaged in an *ongoing activity*. This is not necessarily the case when remembering a past event, since this interruption is externally elicited. 3) Third, the two memory processes differ in the *encoding* mechanism, which is mainly intentional in the case of PM tasks, whereas it can be either accidental or intentional in the case of past events and information. Consequently, planning can be considered as another distinctive feature between RM and PM, since it is highly involved in successful prospective remembering. 4) Fourth, the execution of a previously planned action is time-delimited, since the specific action has to be executed at a precise time or when a particular event takes place. This is generally not the case in situations requiring RM (Guajardo & Best, 2000). 5) Finally, the social and moral aspects are much more relevant in PM tasks, since prospective remembering is often involved in social contexts (Brandimonte, Ferrante, Bianco, & Villani, 2010).

1.3. Phases and Components of Prospective Memory

PM is a complex and multifactorial process which comprehends a variety of cognitive abilities beyond memory. PM can be considered as an umbrella term comprehending the different kind of tasks and the manifold cognitive processes underlying the execution of these tasks (Ellis & Freeman, 2008). A typical PM task is characterized by a delay between the formation and the execution of the intention, the self-initiated interruption of the activities in which we are currently involved, and the execution of the intended action at the right moment. Consequently, the process of prospective remembering can be divided into five sequential phases which involve different cognitive abilities (see Ellis, 1996): encoding, retention, retrieval, execution, and evaluation (see Figure 1).

The *first phase* consists in forming the intention by encoding the content. Specifically, it comprises three elements: the action (*what* we want to do); the setting and criterion of retrieval (*when* we should retrieve the intention and when we want to perform it); and the intent, that is, the determination to perform the action (we decide *that* we do it). The *second phase* refers to the retention interval, that is, the delay period between the formation and retrieval of the intention. This phase can have a variable duration (from minutes to weeks) and represents the period during which the planned action has to be retained until the appropriate moment to execute the intention occurs. Subsequently, the *third phase* refers to the performance interval during which the intention should be retrieved. First, the appropriate retrieval setting should be recognized and the associated intent retrieved (retrieval of the when- and that-components); second, the action encoded in association with these components must be recalled (what-component). The *fourth phase* consists in the execution of the planned action at the right moment, whereas the *fifth phase* refers to the evaluation of the outcome. This final phase enables the archiving of the intention in case of success, or the replanning or reevaluation in case of failure. This phase is important to prevent the irrelevant repetition of an already fulfilled intention, or to enable the successful memory for postponed or forgotten intentions.

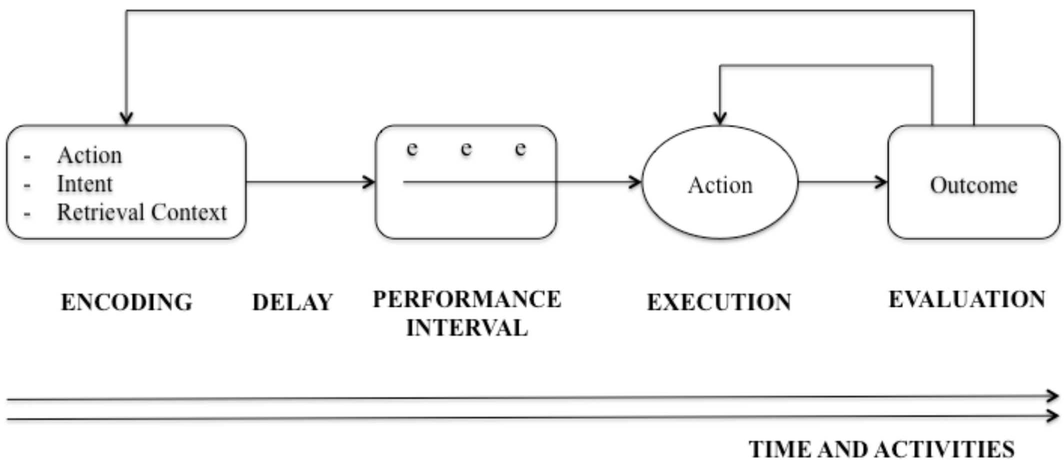

Figure 1. Schematic representation of the specific phases involved in prospective remembering (Ellis, 1996). e = event.

According to Einstein and McDaniel (1990), the processes involved in prospective remembering can be assembled within two components: a retrospective and a prospective component. The *retrospective component* includes all the elements referring to the content of a future intention (the what-, when- and that-elements; Ellis, 1996), thus being based on RM processes. Considering the phases described above, the retrospective component is mainly involved during the encoding and retention phases. The *prospective component* refers to the retrieval of the intended action and its execution at the right moment, thus being mainly involved during the performance interval and execution phases. This component relies mainly on executive and cognitive control processes. For instance, attention has to be switched back and forth from the ongoing activity to the prospective intention and while performing the latter we have to inhibit response to the OT. In fact, abilities such as set shifting and inhibitory control seem to be crucial for the successful execution of delayed intention (Einstein, McDaniel, Marsh, & West, 2008).

1.4. Measuring Prospective Memory in the Laboratory

The ability to remember to perform a previously planned action is commonly measured by means of a dual-task like laboratory-based experimental paradigm proposed by Einstein and McDaniel (1990). This paradigm was designed to mimic an everyday PM situation and consists of two main parts: an ongoing activity (i.e., OT) and an embedded PM task (see Figure 2). The PM task usually lies in executing an action (e.g., pressing a specific button) whenever a particular target or *cue* (e.g., a specific word) occurs (i.e., event-based), after a specific amount of time has passed (i.e., time-based), or after an activity has been executed (i.e., activity-based). It is usually embedded and has to be performed during the OT (e.g., a lexical-decision task). After giving instructions for the ongoing and the PM tasks, participants are usually required to perform an unrelated filler-task. Subsequently, the ongoing and PM tasks have to be performed without repeating instructions to the participants. This procedure aims at simulating the delay period (i.e., retention interval), usually occurring in analogous everyday situations, between forming and executing an intention. The following presentation of the OT represents the performance interval during which the context (i.e., OT) has to be recognized, the intended action retrieved (i.e., instruction for the PM task), and the appropriate moment to execute the action identified (i.e., PM cues). Like in an equivalent everyday situation, whenever the cues occur, participants have to self-initiate the predetermined action without being prompted by the experimenter. Importantly, the frequency of the presentation of the PM cues is relatively low (about 3%), being presented within an OT consisting of hundreds of trials and lasting in total between 15 and 30 minutes (Kvavilashvili, Kyle, & Messer, 2008). Finally, participant's PM performance is generally evaluated considering the number or proportion of times they correctly remembered to perform the predefined action in response to the PM cues.

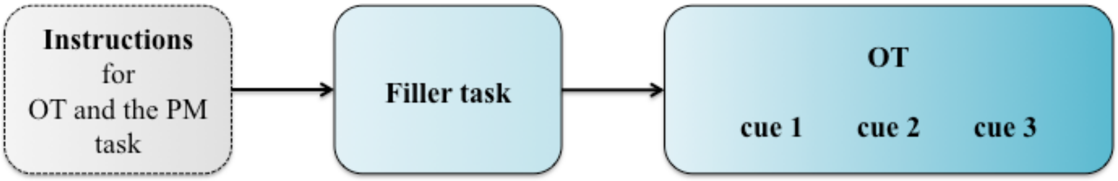

Figure 2. Schematic representation of the classic experimental paradigm of prospective memory (Einstein & McDaniel, 1990). OT = ongoing task; PM = prospective memory.

1.5. Models of Prospective Memory

A main issue in PM research is the nature of memory retrieval, that is, understanding how an intention is retrieved and performed at the predefined moment (Einstein et al., 2008). In the last few years, different theories have been developed trying to define and explain the nature of the manifold processes involved in PM. In the next paragraphs the two main theoretical models addressing this subject will be presented.

1.5.1. Theory of Attentional Monitoring

According to the attentional monitoring view, PM involves an attentional system which monitors the environment in order to detect the PM targets. Once a PM target has been identified, this attentional network suspends the ongoing activity, evaluates the appropriateness of the condition to execute the intended action, and initiates it if favorable. The *preparatory attentional and memory (PAM) theory* (Smith, 2003; Smith & Bayen, 2004) is one of the most developed theories of this kind, claiming that successfully performing a PM task always needs the engagement of capacity-consuming attentional resources. Accordingly, when an intention is formed, preparatory attentional processes are activated in order to monitor the environment for the detection of the PM targets. Thus, the items presented during the OT are checked to establish whether they are part of the PM task or not. As a consequence the cognitive resources necessary to monitor for the correct detection of the targets, are taken away from the OT resulting in cognitive costs (i.e., monitoring costs). These costs can be expressed by slowing of response times (RTs) or increased error rates on the OT when a PM task is present compared to when it is not. Monitoring costs have been revealed by various studies comparing OT performance with and without the presence of a concurrent PM task (Marsh, Hicks, & Cook, 2005; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003; Smith & Bayen, 2004). Moreover, these studies have shown that participants who showed more monitoring costs performed better on the PM task, indicating that attentional monitoring is important for successful prospective remembering.

1.5.2. Theory of Multiple Processes

Differently from the PAM theory, the *Multiprocess* view (McDaniel & Einstein, 2000) and the related recently developed *Dual Pathways* model (McDaniel, Umanath, Einstein, & Waldum, 2015), claim that PM retrieval can rely on either spontaneous (bottom-up) processes or on attentional (top-down) control processes. The authors argue that it is more adaptive to have a network depending on multiple processes for PM retrieval than that theorized by the PAM theory, since attentional resources are limited. Consequently, individuals would mostly rely on automatic and unconscious processes, adopting attentional control processes only when necessary. Accordingly, the involvement of these cognitive control processes depends on different factors determined by ongoing and PM task characteristics as well as individual differences. For example, when an ongoing activity is particularly resource demanding, more attentional monitoring resources are required to perform a concurrently occurring PM task. Similarly, when a PM task is vague and not well specified (i.e., categorical), when its processing is non-focal to the OT, or when it is particularly important, attentional resources will be required to successfully fulfill the intended action, negatively affecting OT performance (Einstein et al., 2005; Marsh et al., 2005; Scullin, McDaniel, & Einstein, 2010; Walter & Meier, 2016). Moreover, individual differences, such as WM capacity can also affect the involvement of attentional resources (Smith & Bayen, 2005). On the other hand, when the PM task is less resource demanding or habitual, when it is well-specified or the association between the cue and the action is high, when its processing is focal to the processing of the OT, then PM retrieval should occur spontaneously without particular cognitive demands and without affecting OT performance (see McDaniel et al., 2015).

2. The Development of Prospective Memory during Childhood

2.1. The Importance of Studying Prospective Memory in Children

PM develops considerably during childhood, permitting children to become more and more independent from parent's help in carrying out the daily requests (Kvavilashvili et al., 2008; Mahy, Moses, et al., 2014a). In early childhood, parents and teachers play an important role in supporting children in remembering to perform daily activities, for example, by giving them helpful and frequent reminders. However, when entering school, children have to begin to remember autonomously to fulfill at least some of adult's assignments, daily activities and personal plans. Being successful on that, is relevant not only for children's academic achievements (e.g., remembering to bring the homework to the teacher or to study for an exam), but also for their social acceptance (e.g., remembering to meet a friend or to return a book to a schoolmate), as well as for their safety and wellbeing (e.g., remembering to put the helmet on when going by bike or to bring a jacket when going on a school trip in the mountains). Studies have shown that having a good PM means also being perceived as a reliable person (Brandimonte & Ferrante, 2008) and in school it has shown to influence evaluation marks that teachers give to children (see Basso & Cottini, 2015).

2.2. Age-Effects on Prospective Memory during Childhood

The number of studies investigating the development of PM during childhood has increased considerably in the last years (see Mahy, Kliegel, & Marcovitch, 2014). PM has shown to be subject to developmental changes occurring across the entire lifespan and to follow an inverted U-shaped course, improving during childhood and adolescence until young adulthood, and decreasing in older age (Zimmermann & Meier, 2006, 2010).

First signs of PM abilities have shown to emerge early in childhood, around the age of 3 and 4 years, improving gradually during the preschool years. Between the ages of 3 and 5 years, children have often shown to become increasingly accurate in remembering to carry out simple and motivating PM tasks in both naturalistic and laboratory-based experiments (Causey & Bjorklund, 2014; Kvavilashvili, Messer, & Ebdon, 2001; Mahy, Moses, & Kliegel, 2014b; Ślusarczyk & Niedźwieńska, 2013; Somerville, Wellman, & Cultice, 1983; Zimmermann & Meier, 2006). Subsequently, important developmental advances in PM have been observed during the first years of primary school, around 7 and 8 years of age. Several studies have shown that during this particular age period, children's accuracy in performing PM tasks improves significantly, representing a critical age for PM development (Kerns, 2000; Smith et al., 2010; Yang et al., 2011). A later important age in PM development has been identified around the age of 10 years. Specifically, from this age on, PM performance has shown to increase through adolescence until young adulthood (Smith et al., 2010; Yang et al., 2011).

2.3. Processes Driving the Development of Prospective Memory during Childhood

Developmental studies have shown that various processes are likely to support age-related improvements in PM during childhood. Apart from RM, which plays an important role in PM development (Smith et al., 2010; Zöllig, West, Martin, Altgassen, Lemke, & Kliegel, 2007), EFs have been identified as one of the major forces driving PM improvements (see Mahy, Moses, et al., 2014a; see Mahy & Munakata, 2015).

2.3.1. The role of executive processes in prospective memory development

EFs refer to the multiple processes involved in the deliberate control of our thoughts, actions and emotions (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000; Zelazo, Craik, & Booth, 2004). It is a hypernym that comprehends abilities such as WM, inhibitory control, set shifting, planning, monitoring and problem solving; abilities which are all potentially involved in PM and in its development.

First, *WM* is used to keep and bring the content of our intention to the focus of attention whenever the appropriate moment occurs. Individuals with high WM capacity have shown to be better at prospective remembering (Marsh & Hicks, 1998; Smith & Bayen, 2005). This may be due to their superior capacity to maintain for a longer time period, or to bring back more rapidly the content of the intention (Mahy, Moses, et al., 2014a). WM develops from early childhood until late adolescence (Gathercole, Pickering, Ambridge, Wearing, 2004), and has been frequently linked to PM development during childhood (Kerns, 2000; Mahy, Mohun, Müller, & Moses, 2016; Mahy & Moses, 2014; Shum, Cross, Ford, & Ownsworth, 2008; Yang et al., 2011). For instance, compared to young children, older children have shown to be better at remembering to perform a PM task after a long retention interval (Mahy & Moses, 2011).

Second, *inhibitory control* is needed to interrupt our automatic response to the OT and to perform the PM task. In fact, PM tasks which require the interruption of an ongoing activity, or PM cues which are non-salient, ill-specified or non-focal to the OT, involve higher levels of inhibitory control. This ability develops considerably during childhood, showing that children become increasingly better in inhibiting prepotent responses especially around the age of 10 years (Brocki et al., 2000; Davidson, Amso, Anderson, & Diamond, 2006; Lee, Bull, & Ho, 2013). Research has shown that inhibitory control plays an important role in PM across the entire lifespan and especially during childhood (Ford, Driscoll, Shum, & Macaulay, 2012; Mahy & Moses, 2011; Shum et al., 2008; Wang, Kliegel, Liu, & Yang, 2008).

Third, *set shifting* plays a crucial part in PM, since attention has to be shifted back and forth from the ongoing to the PM task, whenever a PM cue is detected. PM cues are bivalent in nature, since they usually share similar features with the OT. Moreover, their appearance within an OT is relatively infrequent. Thus, set-shifting demands can be relatively high within a typical PM task

(Meier & Rey-Mermet, 2012). Set-shifting abilities develop significantly during childhood and particularly between 7 and 9 years of age, maturing around the age of 12 (Anderson, 2002).

Finally, *monitoring*, that is, strategically allocating attention towards the detection of PM targets, can play a fundamental part in successfully remembering the execution of an intention, especially when task demands are high (Einstein et al., 2005; Smith, 2003; Smith & Bayen, 2004). Participant's engagement in strategic monitoring during a PM task can be usually observed by slowed OT RTs (i.e., monitoring costs), which has been shown to be positively related to PM performance. The ability to engage in strategic monitoring for the correct detection of PM targets has not yet been consistently studied in children (although see Leigh & Marcovitch, 2014). However, recent lifespan studies have suggested that, compared to adults, children seem to have fewer cognitive resources to engage in strategic monitoring (Kretschmer-Trendowicz & Altgassen, 2016; Smith et al., 2010; see also Cottini & Meier, in preparation).

2.3.2. Other factors related to prospective memory development

Besides executive processes, there are other factors which are likely to drive the development of PM. For instance, it has been suggested that episodic future thinking could be considered as another crucial mechanism underlying age-related changes in PM. The ability to project oneself into the future develops substantially during childhood (Atance & Jackson, 2009). Recent studies have shown that future projection during the intention-encoding phase increased children's probability to remember to execute the intention (Kretschmer-Trendowicz, Ellis, & Altgassen, 2016; Kretschmer-Trendowicz, Schnitzspahn, Reuter, & Altgassen, 2017). Moreover, older children have shown to benefit more from imagining the execution of the future intention than younger children (Kretschmer-Trendowicz et al., 2016).

Another important ability which develops during childhood and which is potentially related to the development of PM is MM (Kvavilashvili & Ford, 2014; Mahy, Moses, et al., 2014a; Spiess, Meier, & Roebers, 2015, 2016). The development of MM has shown to be strongly interrelated with the development of RM (see Schneider, 2015). MM refers to both, declarative knowledge about memory functioning as well as to the ability to apply this knowledge (i.e., using memory strategies, monitoring, controlling and regulating the own memory performance). To date, there is only one study which has explored the relation between MM and PM in children (Kvavilashvili & Ford, 2014; although see Spiess et al., 2015, 2016). Although there is still little evidence, it is likely that MM processes would be relevant for PM development.

2.4. An Executive Framework for Prospective Memory Development

To date there is only one model explaining the development of PM. Basing on theories considering adult's PM (e.g., PAM theory and Multiprocess model) as well as the numerous empirical evidences within developmental research, Mahy and colleagues (2014a) developed an *Executive Framework* to describe the development of PM and its underlying mechanisms. Accordingly, executive control processes play a fundamental role in PM development, being different components of EFs (e.g., WM, inhibitory control, set shifting and monitoring) more relevant than others at different ages and during the different phases of PM. However, similarly to the multiprocess framework, the authors claim that PM relies not exclusively on executive processes but also on associative processes implicated in RM. Consequently, this model makes three main predictions which will be described below.

First of all, a certain degree of executive control is expected to be essential to successfully remember to perform future tasks. Hence, PM abilities in very young children will be scarce, since their executive abilities are still immature. Second, age-related improvements in EFs are expected to predict better PM abilities, especially in highly resource demanding tasks. Third, different components of EFs are predicted to be more or less influential on PM development at different ages. For instance, the development of elementary WM skills in young children should support the ability to maintain simple intentions in memory and to bring them back to the focus of attention when needed. Consequently, children aged between three and five years, are expected to be capable of keeping an intention in the focus of attention, but they would probably have difficulties in carrying out the intended action, since their WM and inhibitory control abilities are still at a basic developmental stage (Davidson et al., 2006). During the school years, children's attentional monitoring, inhibitory control and set-shifting abilities improve gradually (Anderson, 2002; Davidson et al., 2006). Consequently, children are expected to become increasingly able to interrupt a resource demanding ongoing activity in the right moment, and to shift the attention to the PM task and back again. Moreover, WM and planning skills are expected to be more influential during the encoding phase and the retention interval, whereas inhibitory control and set-shifting abilities are predicted to influence mainly OT performance and PM cue detection.

To summarize, this model predicts that EFs directly influence PM, being the major force driving its development. However, it is likely that also other processes, such as MM would have a strong impact on PM and its development. Although, there is little evidence in this realm, advances in MM knowledge and awareness are likely to play a fundamental role in children's PM.

3. Metamemory and its Development during Childhood

3.1. Definition of Metamemory and Importance in Everyday Life

MM refers to the all the explicit and conscious knowledge about memory and memory-related aspects concerning information storage and retrieval (Flavell & Wellman, 1977). MM is commonly differentiated in declarative and procedural MM. *Declarative MM* refers to all the verbalizable knowledge, believes and awareness about factors influencing memory as well as reasons for their influence. This includes, for example, information related to the impact of variables inherent to the person, the task, or the strategies to use in different situations. On the contrary, *procedural MM* refers to the application of this knowledge. This includes use of strategies, as well as control, regulation and monitoring of the own memory performance.

3.2. How is Metamemory measured?

3.2.1. Declarative Metamemory

Declarative MM is commonly measured by means of interviews and questionnaires including items evaluating knowledge of various memory processes (Schneider, 2015). For instance, one of the first interview studies with children, which was conducted by Kreutzer and colleagues (Kreutzer, Leonard, Flavell, & Hagen, 1975), included questions inherent to person, task and strategy variables related to memory performance in different situations. In particular, they evaluated children's comprehension of common everyday memory phenomena including both retrospective and prospective tasks (e.g., remembering how long one has owned a dog, or remembering to bring the skates to school the next day, respectively). Other methods to study MM knowledge have been developed in the subsequent years to overcome the limitations resulting from these investigation forms. For instance, some researchers used vignettes depicting different actors involved in different everyday memory tasks (Wellman, 1977; Yussen, Levin, Berman, & Palm, 1979). Knowledge about the effect of age, time, or strategy use were evaluated by asking children to select the picture representing the condition in which it is more likely to remember. Furthermore, Cornoldi, Gobbo, and Mazzoni (1991) developed a narrative task to assess children's MM knowledge. This consisted in telling a story during which the children were asked questions evaluating their knowledge of forgetting, retrieval and storage strategies.

3.2.2. Procedural Metamemory

Procedural MM is usually assessed in conjunction with a memory task by asking participants to judge the own memory performance either before, during or after performing the task (see Schneider, 2015). Self-monitoring, namely, the online evaluation of ones own memory performance is the most used method to study procedural MM. The literature has concentrated on various kinds of self-judgments, such as performance predictions or ease-of-learning judgments, judgments of learning, as well as postdictions, confidence judgments and allocation of study time.

Performance predictions refer to judgments which are made before a memory task, thus, being highly inferential. This paradigm has been used for example, before testing the WM span (Bertrand, Moulin, & Souchay, 2017). Here, participants are usually presented with a series of increasingly longer words- or picture-lists, and are asked before each list whether they would be able to recall the items or not. After judging each future performance, participants are tested on that list. MM values are then obtained by comparing predictions with actual memory performance.

Similarly, *judgments of learning* refer to predictions about the ability to recall recently studied memory items, and are usually made while or immediately after their acquisition. Judgments of learning are typically used with paired associate learning tasks (see Schneider, 2015). For instance, after learning a word-pair, participants are presented with one of the two words and are required to judge whether they will be able to correctly recall the associated item either immediately or after some minutes (i.e., immediate or delayed judgments of learning, respectively).

Other studies evaluated also *postdictions*, asking participants how many items they remembered correctly as well as how sure they were of their judgment (i.e., confidence judgment). *Confidence judgments* can be assessed after making any kind of judgment (e.g., after a performance prediction or a postdiction), and are frequently established on a Likert scale indicating different levels of confidence (Roebers, 2002; Roebers, von der Linden, Schneider, & Howie, 2007).

Finally, developmental studies have frequently investigated self-monitoring and -regulation skills, such as the allocation of study time (see Schneider, 2008, 2015). This research method permits to examine the ability to allocate attention and effort while studying different learning materials. First, participants are presented with wordlists which they have to learn. Then, after a first free-recall test phase, they are asked to identify the non-recalled items (i.e., self-monitoring). Finally, they can choose half of the items to restudy them (i.e., self-regulation).

3.3. Age-Effects on Metamemory during Childhood

Studies on declarative MM revealed some elementary knowledge about memory in preschoolers and first-graders (Kreutzer et al., 1975). Children of this age seem to begin to understand the meanings of learning, remembering and forgetting and other mnemonic expressions. During the primary school years MM knowledge improves considerably. For instance, between the beginning and the end of primary school the verbalizable knowledge about memory is acquired and increases importantly. Whereas between 3 and 6 years of age, knowledge about memory is global and general, children between the age of 7 or 8 and 10 years have a better awareness of memory processes. During this age period, children’s knowledge regarding memory functioning, personal attitudes, task characteristics, as well as memory strategies increases substantially (*ibidem*).

After the age of 10 years up to adolescence and adulthood MM knowledge becomes more and more complex and also the use of the strategies more skillful. Indeed, there are some studies showing that procedural MM develops later and slower than declarative MM, suggesting that the development of declarative MM precedes that of procedural MM (Fritz, Howie, & Kleitman, 2010). Researchers argued that declarative MM is promoted by language development and is also strongly related to IQ, showing that it follows a domain-general developmental trajectory. In contrast procedural MM has shown to involve monitoring and cognitive control processes. Consequently its development seems to be more dependent on EFs and has been found to develop separately from general intelligence (*ibidem*). Moreover, it has been shown that training in strategy use enhances memory performances (Cornoldi et al., 1991). This indicates that repeated exposure and experience with similar problems are able to improve procedural MM ability.

The relation between declarative and procedural MM has shown to emerge during the primary school years, becoming stronger with increasing age. Developmental studies have shown that the link between MM knowledge, strategy use and memory ability is weak in preschool and first primary school years (between 4 and 7 years of age), while it increases in subsequent years (Lange, Guttentag, & Nida, 1990). This is supported by a broad statistical meta-analysis considering more than 60 studies investigating the interrelation between strategy knowledge and memory performance and including a total of 7,000 children and adolescents (see Schneider, 1985). Correlations between procedural and declarative MM tended to be weaker in preschoolers and in first and second graders, while they became more robust starting from the third and fourth grade. Importantly the correlation's size seemed to depend on variables such as task type, age, task difficulty and when the MM evaluation took place (before or after the memory task was administered).

3.4. The Role of Metamemory in Prospective Memory

3.4.1. Metamemory and Prospective Memory in Adults

Whereas MM has been widely studied in relation to RM, showing its central role in remembering past events, there are only few studies on PM. The majority of these studies included adult samples and investigated procedural MM in conjunction with different PM tasks (Meeks, Hicks, & Marsh, 2007; Meier, von Wartburg, Matter, Rothen, & Reber, 2011; Rummel, Kuhlmann, & Touron, 2013; Schnitzspahn, Zeintl, Jäger, & Kliegel, 2011). For instance, Meeks and colleagues (2007) adopted a prediction-postdiction paradigm to study the role of procedural MM in PM. Specifically, they asked participants to perform a lexical decision task and to remember to press a specific key whenever a particular cue appeared (in one group an animal word and in the other group a specific syllable). After receiving instructions, they had to predict their future performance by indicating the percentage of PM cues they expected to detect. Finally, after performing the task they were asked to judge their PM performance by indicating the percentage of cues they have detected. Results revealed that both predictions and postdictions in both groups were lower than the actual PM performance. Similarly, results of a more recent study (Schnitzspahn et al., 2011) revealed that adults underestimated their PM performance in both an immediate and a delayed judgment-of-learning condition. Meeks and colleagues (2007) argued that being underconfident is probably an adaptive characteristic, eliciting a more frequent refreshment of the unfulfilled intention. Thus, being underconfident of fulfilling a PM task would be positively related to the successful completion of the intention. This has been shown also in RM research, where underconfidence emerged especially with practice of a task being highly related to an increased performance (underconfidence-with-practice effect; Koriat, Sheffer, & Ma'ayan, 2002). Similarly, in Schnitzspahn and colleagues' study (2011), adult participants generally underestimated PM performance, although, when performance judgments were delayed, prediction accuracies moderately increased. The authors disentangled the prospective and retrospective component of PM in order to compare metacognitive judgments for the two processes. Results revealed that predictions related to the prospective component were characterized by a general underconfidence, whereas those for the retrospective component changed with practice replicating the underconfidence-with-practice effect often found in the RM literature (Koriat et al., 2002).

An interesting hypothesis emerging from these first two studies was that making predictions about the future performance might has increased salience or importance of the PM task, directly influencing performance. In this vein, two following studies aimed at investigating this possible effect of making MM judgments on PM performance in adults (Meier et al., 2011; Rummel et al., 2013). First, Meier and colleagues (2011) compared a group receiving standard instructions for a PM task with a group that was additionally required to make predictions about the future performance. Moreover, for half of the participants the PM target was categorical (i.e., a musical instrument) and for the other half it was specific (i.e., a trumpet). Results revealed that participants who were asked to predict their future performance had a significantly higher PM accuracy than those in the control condition. However, this prediction-advantage emerged only in the categorical and not in the specific PM task. After performing the task, participants were asked whether they searched for the PM target or whether it *popped* into their mind. Interestingly, both performance prediction and cue specificity were related to retrieval experience. In the categorical condition the number of participants who reported a search experience was higher than in the specific condition and, importantly, performance predictions increased the probability of actively searching for the categorical PM cue. Concerning prediction accuracy, results were rather inconsistent, with a significant relation between predictions and actual PM performance in the categorical condition, and no significant relation in the specific condition. The authors' conclusion was that making predictions is likely to enhance the perceived importance of the prospective intention, resulting in higher monitoring levels.

Starting from these evidences, Rummel and colleagues (2013) conducted a further study to shed light on the prediction-effect on PM performance. Specifically, they were interested in studying whether making performance predictions would have affected the allocation of attention to the PM task. Adult participants were asked to perform a lexical decision task; the first experiment included a categorical PM task, whereas the second experiment included a specific PM task. A third of the sample had to make PM performance predictions, a third was asked to make both ongoing and PM performance predictions, while the remaining participants served as control. In both experiments (i.e., categorical and specific PM task) making exclusive PM performance predictions significantly slowed down OT performance, showing that predictions reactively enhanced attentional monitoring processes. Similar to Meier and colleagues' study (2011), PM performance was higher in the PM prediction group compared to the control group, but only in the categorical task. On the other hand, the group with both ongoing and PM predictions did not differ neither from the control group nor from the PM performance prediction group. Concerning prediction accuracies, participants in the first experiment overestimated, whereas those in the second experiment underestimated their PM performance. Moreover, in none of the two experiments predictions were related to actual performance, indicating that participants had little insight in their future performance. The authors argued that without prior task experience, participants rely more on their global expectations of the own performance based on information extracted from the received instructions. Consequently, performance predictions may not be informative of participant's MM abilities. However, performance predictions might be a helpful tool to understand individual's cognitive strategies employed to remember to execute future intentions (Rummel et al., 2013).

3.4.2. Metamemory and Prospective Memory in Children

There are several studies on the development of children's MM in relation to RM (e.g., Fritz, Howie, & Kleitman, 2010; Roebers, von der Linden, Schneider, & Howie, 2007; Schneider, 2008), but there is only one study to date on the relationship between MM and PM in children (Kvavilashvili & Ford, 2014; although see Spiess et al., 2015, 2016). Kvavilashvili and Ford (2014) investigated MM prediction accuracy of preschool children for both a prospective and a retrospective memory task. Replicating previous MM-RM studies, their results revealed that children's performance predictions on a memory-recall task were generally overestimated. On the contrary, children's performance predictions on an event-based PM task were relatively accurate and related to their actual PM achievements. One possible explanation according to the authors was that performance predictions involved future thinking, which has shown to be positively related to PM (e.g., Kretschmer-Trendowicz et al., 2016). In fact, projecting one-self into the future and imagining to perform a PM task, has shown to enhance subsequent PM performance by increasing cue saliency and strengthen intention encoding (e.g., Brewer, Knight, Meeks, & Marsh, 2011). Consequently, the authors suggested that future thinking may not only be responsible for enhancing PM performance, but would be likely to positively influence subjective confidence related to the future performance. On the other hand, they argued that performance predictions concerning RM abilities would probably rely more on declarative MM rather than on future thinking processes.

4. Aims and Research Questions

The main purpose of the current dissertation was to investigate the role of procedural and declarative MM in PM of 7- and 8-year-old children. This particular age period was chosen because it has been identified as being critical for the development of PM during the school years. In three experimental studies, 7- and 8-year-old children's PM were tested using different PM tasks in association with different MM paradigms (i.e., prediction paradigm, prediction-postdiction paradigm, strategy use). Moreover, the contribution of EFs to PM performance in the various experimental conditions was tested basing on the Executive Framework of PM development (Mahy, Moses et al., 2014a). For statistical analyses, mixed-effects regression models were adopted to examine the involvement of both EFs and declarative MM in PM performance. This statistical method enabled us to get an overall picture of data including fixed and random effects, aiming at improving statistical power.

In the next paragraphs, four research questions will be discussed in detail. The first examines whether and how making performance predictions prior to different PM tasks would improve children's PM performance. The second investigates children's ability to judge the own PM performance before and after performing a PM task, as well as their awareness of whether and which strategy they have used to perform it. The third research question concerns the role of declarative MM and EFs in children's PM. Finally, the fourth research question regards the investigation of longitudinal relations between the development of PM and MM in children aged 7 and 8 years.

4.1. Can Performance Predictions Benefit Children's Prospective Memory on a Resource-Demanding Task?

In adults, making performance predictions has shown to improve PM performance on a resource-demanding (i.e., categorical) but not on a less resource-demanding (i.e., specific) PM task (Meier et al., 2011; Rummel et al., 2013). The role of procedural MM in PM of school-aged children has not been investigated yet. In RM research, procedural MM has shown to be increasingly related to RM performance, with children from 7 years ahead being increasingly able to translate their performance judgments in effective strategy use and control of memory performance (Lockl & Schneider, 2003). The aim of Study 1 was to investigate whether and how performance predictions would increase PM performance of 7-year-old children. Moreover, the role of declarative MM as well as EFs on PM performance has been examined. To this purpose, two groups of children, one with and one without performance predictions were compared on two different PM tasks: one including categorical (i.e., resource-demanding) and one specific PM cues (i.e., less resource-demanding). Besides PM performance, OT RTs were compared between groups and tasks in order to examine prediction-induced monitoring costs revealed in previous studies with adults (Rummel et al., 2013).

4.2. How does Procedural Metamemory relate to Children's Prospective Memory?

To date, procedural MM has been rarely studied in relation to PM. These studies included mainly adult samples, and operationalized procedural MM primarily as performance predictions. Whereas adults mainly underestimated subsequent PM performance (e.g., Meeks et al., 2007; Schnitzspahn et al., 2011), preschool children showed to be quite accurate in predicting performance on a simple PM task (Kvavilashvili & Ford, 2014). RM studies using this paradigm have frequently shown that predictions were not related to actual performance and that they would probably be influenced by other factors different from MM (see Schneider, 2015). On the other hand, postdictions have shown to be highly related to memory performance, thus being more informative of individual's procedural MM. To date, only one study has investigated procedural MM in association to PM by using a postdiction paradigm. Meeks and colleagues (2007) asked adults to judge their PM performance before and after performing a PM task. Results revealed that postdictions were strongly related to PM performance, with a tendency towards underestimation of performance. Finally, children's strategy use in relation to PM has never been systematically studied yet (although see Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005). RM research revealed that, although children's knowledge about memory strategies may be accurate, they become able to translate it in effective control of performance only later in childhood (Lockl & Schneider, 2003).

Given these evidences, the second research question regarded the examination of children's insight in their personal PM performance as well as their ability to translate MM knowledge in effective control of PM performance. To this purpose, children's performance judgments made before and after performing the PM task were examined in relation to actual PM performance. Moreover, children were asked whether and which strategy they have used to perform the task, in order to examine its effect on PM performance.

4.3. How do Executive Functions and Declarative Metamemory relate to Children's Prospective Memory?

As summarized and discussed in the Executive Framework of PM development (Mahy, Moses et al., 2014a), age-related advances in PM during childhood seem to be mainly driven by the development of EFs, especially when executive demands are high. Moreover, the model claims that a certain grade of executive control is always needed to successfully perform a PM task. Age differences in PM should dependent on the development of EFs as well as on specific task demands. Accordingly, children's abilities in inhibitory control, set shifting and monitoring would be specifically related to OT and PM performance, whereas WM would play a major role in the formation and retention of the intention.

Besides being based on the Multiprocess view (Einstein et al., 2005) and the PAM model (Smith, 2003; Smith & Bayen, 2004), the predictions of the Executive Framework were built on recent studies on the role of EFs in children's PM. Given the lack of research on the role of MM in children's PM (although see Kvavilashvili & Ford, 2014), the authors could not include related predictions in their model. However, they argued that MM is likely to influence PM development. Consequently, the second research question of the present work was related to the specific contribution of EFs and declarative MM to PM performance on the different tasks. To this purpose, measures of declarative MM, inhibitory control, set shifting and WM have been included in the various experiments of this work.

4.4. How does Prospective Memory Develop between 7 and 8 years of age, and how does this development relate to Metamemory and Executive Functions?

Important developmental advances in PM seem to occur particularly between the age of 7 and 8 years. As suggested by the Executive Framework (Mahy, Moses et al., 2014a), developmental improvements in PM during this age period are likely to depend on advances in executive processes, such as inhibitory control, WM and monitoring. This has been confirmed by some recent studies comparing different age groups using cross-sectional designs. However, recently a study has examined the longitudinal relations between the development of PM and EFs in children between 7 and 8 years of age. This confirmed previous studies, showing that EFs were highly related to developmental advances in PM. However, developmental research has neglected to date the role of MM in PM development. In fact, recent studies suggested that MM would play an important role in PM advances during childhood (Kvavilashvili & Ford, 2014). For this reason, the fourth research question concerned the exploration of longitudinal relations between PM, MM and EFs.

Consequently, the same children were evaluated on the same tasks at two different time points with a mean delay of 12 months between the first and the second. PM was assessed using the more resource-demanding PM task of Study 1 (i.e., categorical PM task) and the performance prediction paradigm for procedural MM. Declarative MM, inhibitory control and WM abilities were measured as well. Moreover, children were asked about their retrieval strategy (strategic vs. automatic) in order to see whether this would change and influence PM performance over time.

5. Study 1: The Role of Declarative and Procedural Metamemory in Event-Based Prospective Memory in School-aged Children

5.1. 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 et al., 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, et al., 2014a). 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.

5.1.1. 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, WM (WM), set shifting, and monitoring (e.g., Spiess, Meier, & Roebers, 2016; Yang et al., 2011).

Mahy, Moses, et al. (2014a) 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 effectively, particularly when executive demands of the task are high. Furthermore, the authors claimed that different EFs 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.

5.1.2. Metamemory and its relation to prospective memory

MM 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 fore- casts 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. More- over, 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 OT, suggesting that performance predictions enhanced the engagement in strategic monitoring.

5.1.3. 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., 2014a).

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 relation- ship between procedural MM and PM, and the paradigm would prove to be insufficiently sensitive for our goals.

5.2. Method

5.2.1. 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.

5.2.2. 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). 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).

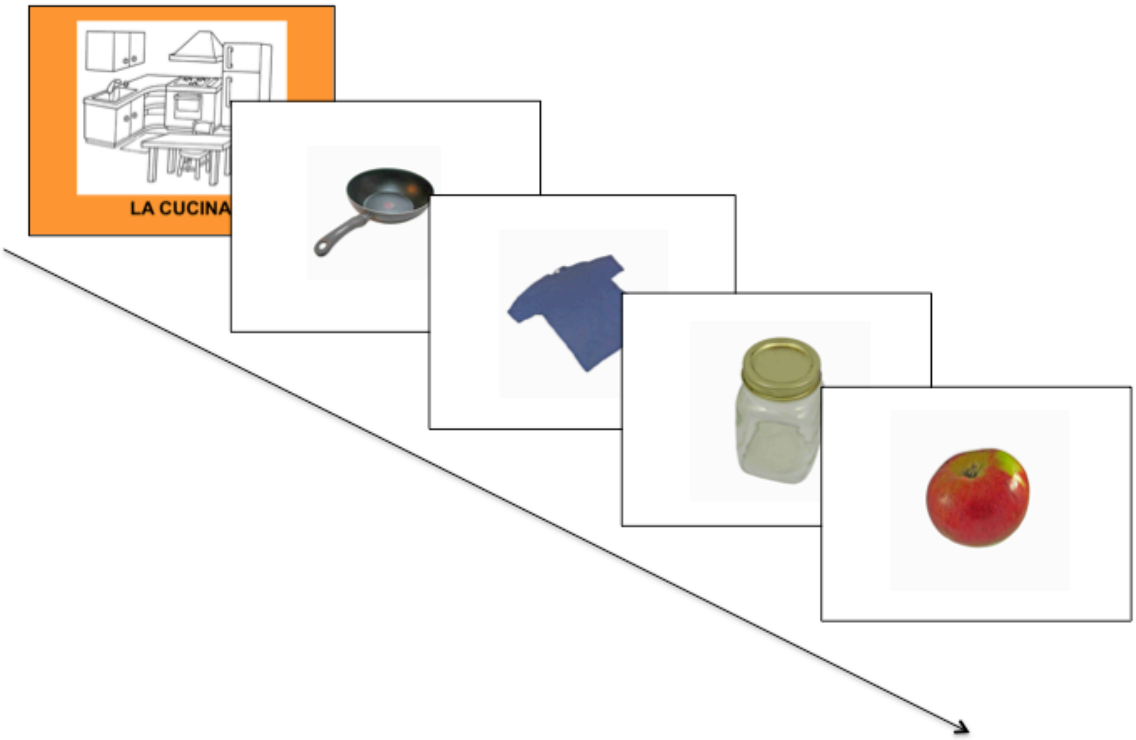

Figure 3. Schematic representation of the ongoing task. At the beginning of each block the picture and name of the category is presented (e.g. "La cucina", Italian for "the kitchen"). Afterward, ongoing task stimuli are presented one by one. In the example, a PM cue is included (last picture of the sequence).

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 mea- sure of declarative MM showed good internal consistency, resulting in an overall α 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.

5.2.3. 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.

5.3. Results

5.3.1. 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): $F(11, 44) = 0.413$, $p = .942$, Pillai's trace = 0.094, $\eta^2_p = .02$. 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, $p = .994$, $\eta^2_p < .01$.

Table 1

Means (and standard deviations) of raw scores at the various tests included in this study.

	Non-prediction group (*n* = 30)	**Prediction group** (*n* = 29)	**Actual range**
Age (in years)	7.42 (0.29)	7.32 (0.25)	−
Gender	M = 13; F = 17	M = 13; F = 16	−
Cognitive Measures			
PMA verbal abilities	25.93 (1.91)	25.34 (2.26)	0−30
PMA non-verbal abilities	13.93 (4.95)	14.65 (4.63)	0−27
Inhibitory control (errors)	1.37 (1.07)	1.55 (1.21)	−
Digit Span forward	4.40 (0.77)	4.14 (0.74)	−
Digit Span backward	2.83 (0.70)	2.76 (0.69)	−
Declarative MM story task			
Knowledge of forgetting	8.40 (2.08)	8.24 (1.62)	0−14
Knowledge of storage	2.67 (1.37)	2.86 (1.38)	0−4
Knowledge of retrieval	1.57 (1.33)	1.59 (1.21)	0−4
Declarative MM total	12.63 (3.65)	12.69 (2.95)	0−22

Note. M, male; F, female; PMA, Primary Mental Abilities; MM, metamemory.

5.3.2. 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).

Table 2

Confidence judgments of performance predictions related to the number of remembered cues in the categorical and specific prospective memory tasks.

Task	**Confidence**	**Total**	**Remembered**			
			0	**1**	**2**	**3**
Categorical	sure	12	4	1	3	4
	very sure	15	2	3	4	6
Specific	sure	10	0	0	1	9
	very sure	16	5	3	1	7

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 per- formed worse than those who were more conservative in predicting their performance.

5.3.3. 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.

Table 3

Mixed-effects regression model for ongoing task performance.

Fixed effect parameters	**Accuracy**			**Reaction time**		
	β (*SE*)	z	*p*	*β* (*SE*)	*t*	*p*
Intercept Group0, Task1	2.953 (0.138)	21.37	<.001	6.896 (0.088)	78.72	<.001
Group1 = with predictions	0.187 (0.159)	1.17	n.s.	0.068 (0.026)	2.60	<.05
Task2 = specific	0.150 (0.129)	1.15	n.s.	0.001 (0.008)	0.08	n.s.
Group1 × Task2	/			−0.079 (0.011)	−7.39	<.001
Inhibition Errors	−0.171 (0.058)	−2.95	<.01	/		
Log(Preceding Trial)	/			0.101 (0.011)	9.13	<.001
Random effect Parameters	*SD*			*SD*		
Random effect Stimuli	/			0.083		
Random effect Participants	0.321			0.094		
Residuals				0.232		

Note. The model for accuracy has been computed using all responses (correct and incorrect ones) through this formula: glmer(accuracy ~ group + task + InhibitionErrors + (1 | Participants), data = ongoing_accuracies, family="binomial"). The model for reaction times was computed using the correct responses only, through this formula: lmer(log(ongoing_RTs) ~ group*task + log(Preceding Trial) + (1 | Stimuli) + (1 | Participant), data = ongoing_RTs.

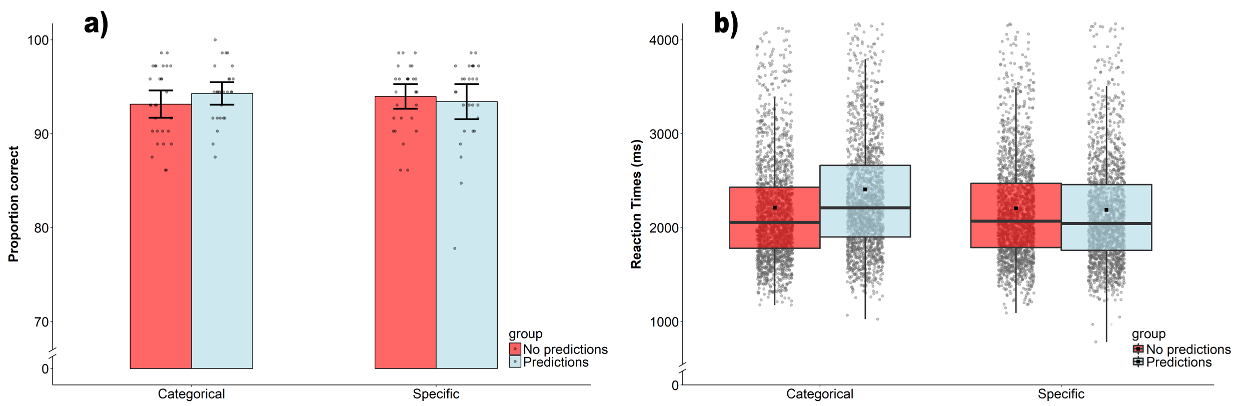

Figure 4. Ongoing task (OT) performance including either categorical or specific cues represented by mean proportion **(a)** and RTs **(b)** of correct responses for the non-prediction and the prediction groups. In graph **(a)**, error bars represent one standard error, while points represent the values for each subject. In graph **(b)**, upper and lower limits of the boxes represent the 25^{th} and 75^{th} quartile, while 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, while the gray dots indicate each single RT.

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 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 non-significant main effect of declarative MM and the significant interaction of Group1 × Declarative MM indicate that MM 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.

Table 4

Mixed-effects regression model for prospective memory performance.

Fixed effect parameters	**Accuracy**			**Response time**		
	β (*SE*)	z	*p*	*β* (*SE*)	*t*	*p*
Intercept Group0, Task1	−16.512 (4.682)	−3.526	<.001	7.857 (0.124)	63.32	<.001
Group1 = with predictions	4.092 (1.068)	3.831	<.001	−0.410 (0.195)	−2.11	<.05
Task2 = specific	3.631 (2.080)	1.746	=.081	−0.083 (0.029)	−2.90	<.01
Group1 × Task2	−5.049 (1.130)	−4.468	<.001	/		
Declarative MM	0.332 (0.137)	2.414	<.05	/		
WM Span Forward	1.504 (0.682)	2.204	<.05	/		
Group1 × Declarative MM	/			−0.031 (0.015)	−2.14	<.05
Random effect Parameters	*SD*			*SD*		
Random effect Stimuli	3.689			/		
Random effect Participants	2.651			0.133		
Residuals				0.169		

Note. The model for accuracy has been computed using all responses (correct and incorrect ones) through this formula: glmer(accuracy ~ group*task + Declarative_MM + WM_Span_Forward + (1 | Stimuli) + (1 | Participants), data = ongoing_accuracies, family="binomial"). The model for reaction times was computed using the correct responses only, through this formula: lmer(log(RTs) ~ group* Declarative_MM + task + (1 | Participant), data = prospective_RTs.

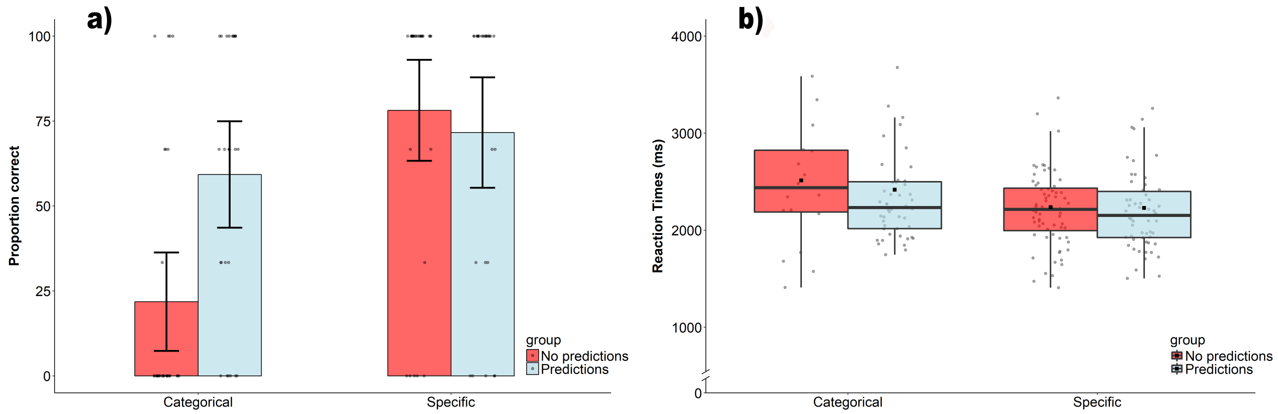

Figure 5. Prospective memory (PM) performance including either categorical or specific cues represented by mean proportion **(a)** and RTs **(b)** of correct responses for the non-prediction and the prediction groups. In graph **(a)**, error bars represent one standard error, while points represent the values for each subject. In graph **(b)**, upper and lower limits of the boxes represent the 25th and 75th quartile, while 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, while the gray dots indicate each single RT.

5.3.4. 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 pre- diction 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.”

In the specific condition, the models converged for PM accuracy (intercept, Pred1 = ‘‘very sure”: $\beta = -13.353$, $SE = 5.124$, $z = -2.61$, $p <.01$; Pred2=‘‘sure”: $\beta = 6.865$, $SE = 2.556$, $z = 2.69$, 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”: $\beta = 7.739$, SE = 0.290, $t = 26.64$, $p < .001$; Pred2 = ‘‘sure”: $\beta = -1.285$, $SE = 0.564$, $t = -2.28$, $p < .05$;

declarative MM: $\beta = -0.034$, $SE = 0.014$, $t = -2.34$, $p < .05$; 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.

5.4. 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., 2014a). 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., 2014a), 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 EFs (see Roebers & 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 Kvavilashvili 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 mea- sure 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, submitted for publication) 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.

5.4.1. 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 pre- diction, 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.

6. Study 2: Performance Predictions and Evaluations in Prospective Memory in School-aged Children

6.1. Introduction

Remembering to execute a planned action in a specific moment in the future, such as picking up dry-cleaning, delivering a message to a colleague, taking vitamins or stopping at the grocery to buy bread while driving home from work, is defined as prospective memory (PM; Einstein & McDaniel, 1990). PM is a crucial ability for successful achievement of daily goals across the entire lifespan and in a variety of contexts (e.g., academic, work, social relationships, heath and wellbeing). Starting from the early primary school years, children are required to remember to perform some of their own intended actions, or assignments from others (see Mahy, Moses, & Kliegel, 2014a).

Environmental demands as well as cognitive maturation are probably responsible for developmental improvements in PM. In fact, during these years, the ability to execute delayed intention has shown to increase considerably, and to be strongly related to the development of executive functions (EFs; see Mahy, Moses, & Kliegel, 2014a; see Mahy & Munakata, 2015). For instance, children's PM performance has shown to improve particularly between the age of 7 and 8 years (Kerns, 2000; Smith, Bayen, & Martin, 2010; Spiess, Meier, & Roebers, 2016; Yang, Chan, & Shum, 2011). Cognitive abilities such as working memory (WM), inhibitory control, switching and monitoring have been significantly linked to this development (Spiess et al., 2016; Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005; Yang et al., 2011). However, there is an important cognitive aspect that has been often neglected in the PM development research, namely the role of metamemory (MM; although see Spiess et al., 2016). So far, not many studies have examined the relation between PM and MM in children (Cottini, Basso, & Palladino, 2018;

Kvavilashvili & Ford, 2014; see also Spiess, Meier, & Roebers, 2015), and filling this gap was the primary aim of the present investigation.

6.1.1. The development of metamemory

MM refers to both explicit knowledge and awareness about memory and memory-related processes (i.e., declarative MM), as well as the application of this information, such as using strategies, controlling, regulating and monitoring the own memory performance (i.e., procedural MM; Kreutzer, Leonard, Flavell, & Hagen, 1975). Whereas declarative MM is assessed by means of questionnaires, interviews or story tasks (e.g., Cornoldi, Gobbo, & Mazzoni, 1991; Kreutzer et al., 1975), procedural MM is typically evaluated in association with a memory task (e.g., Roebers, Krebs, & Roderer, 2014; Roebers, von der Linden, Schneider, & Howie, 2007). For instance, participants can be asked to predict, judge or monitor the own memory performance before, during or after a memory task. The more accurate these judgments are compared to the actual memory performance, the better the individual's insight into their own memory functioning (see Schneider, 2015).

Developmental research revealed that MM improves during the primary school years (Fritz, Howie, and Kleitman, 2010; Schneider, 1986), with advances in declarative MM supported by language and reasoning abilities (Schneider, Kerkel, & Weinert, 1987); those in procedural MM are related to monitoring and control processes (Isingrini, Perrotin, & Souchay, 2008). The relation between the two MM components seems to emerge only after 7 or 8 years of age. Thus, the interplay between knowing about memory, using effective strategies, regulating and controlling one's own memory performance shows improvement only later in the school years (Lockl & Schneider, 2003). This development seems to be related to growing experience with different, increasingly complex memory tasks during the school years (see Schneider, 2015). Children's procedural MM has been widely studied in relation to retrospective memory (RM) and these studies have shown that children tend to overestimate the own memory performance, becoming more accurate with increasing age (see Schneider, 2015).

6.1.2. The relation between metamemory and prospective memory during childhood

Despite the broad range of studies showing the important role of MM in children's RM, to date there are few studies which have examined MM in relation to children's PM (Cottini et al., 2018; Kvavilashvili & Ford, 2014). Kvavilashvili & Ford (2014) were the first to reveal a significant relation between procedural MM and PM in preschoolers. In their study, 5-year-old children were relatively accurate in predicting their future performance on a simple PM task. However, they overestimated future performance on a RM task. According to the authors, performance predictions and PM are likely to share similar processes, such as episodic future thinking. In fact, projecting oneself into the future resulted in improvement of children's subsequent PM performance (Kretschmer-Trendowicz, Ellis, & Altgassen, 2016).

Consequently, it is likely that performance predictions could have a similar boosting effect on PM performance; in fact, the direct effect of performance predictions on subsequent PM performance has first been shown in adults (Meier, von Wartburg, Matter, Rothen, & Reber, 2011; Rummel, Kuhlmann, & Touron, 2013). Here, participants, who had to predict subsequent PM performance, outperformed a control group without a performance prediction requirement. However, PM improvements resulting from performance predictions were observed only in categorical/more resource-demanding PM tasks (i.e., remembering to execute an action whenever a category of cues appeared), rather than, specific/more automatic PM tasks (e.g., remembering to execute an action whenever well-specified cues appeared). A similar pattern emerged also in a previous study with 7-year-old children (Cottini et al., 2018). Children who had to predict PM performance performed better than children in a control group. Similarly to adult studies, this advantage emerged only in a categorical, but not the specific, PM task (Meier et al., 2011; Rummel et al., 2013). Additionally, this advantage was associated with slower response times (RTs) to the ongoing task (OT), suggesting that attentional monitoring processes were enhanced by predictions (Rummel et al., 2013). However, although the children in the prediction group were relatively able to predict the direction of future performance, their confidence judgments were imprecise and not related to actual performance.

The inconsistent (and frequently non-existent) relation between prediction judgments and actual PM performance also emerged with adults (e.g., Meeks, Hicks, & Marsh, 2007; Rummel et al., 2013; Schnitzspahn, Zeintl, Jäger, & Kliegel, 2011), suggesting that performance predictions may be not a pure measure for procedural MM. For instance, previous RM studies have shown that performance predictions can be influenced by several factors unrelated to MM, such as motivation (i.e., wishful thinking hypothesis; Schneider, 1998), task familiarity, task experience or evaluation mode (e.g., Visé & Schneider, 2000). On the other hand, asking participants to judge their own memory performance after performing a task (i.e., postdictions) has shown to be a more reliable measure of procedural MM (see Schneider, 2015). Similarly, in a study with adults, Meeks and colleagues (2007) showed that while relation between predictions and PM performance was inconsistent, postdictions were highly related to actual PM performance.

6.1.3. The current study

The primary aim of the present investigation was to explore the relation between procedural MM and PM in 7- and 8-year-old children. In addition, we examined the contribution of declarative MM and EFs to children's PM. This age period has frequently been shown to be critical for development of PM (Kerns, 2000; Smith et al., 2010; Spiess et al., 2016; Yang et al., 2011), procedural and declarative MM (Schneider, 2015), EFs (Brocki & Bohlin, 2004), as well as their interrelation (Cottini et al., 2018; Spiess et al, 2016).

In the present study, we assessed children's ability to judge their performance before (predictions) and after (postdictions) executing a specific PM task. Additionally, we asked children whether they used a strategy to remember to perform the PM task, and if so, which strategy.

Performance predictions have shown to improve subsequent PM performance on a categorical, but not a specific PM task, in both adults and children (Cottini et al., 2018; Meier et al., 2011; Rummel et al., 2013). However, Rummel and colleagues (2013) showed that making performance predictions reactively changed subsequent OT performance. This slowed RTs in both categorical and specific PM conditions, but improved PM performance only in the categorical condition. Accordingly, performance predictions might have affected the engagement of attentional monitoring processes generally, but was functional only for the categorical (and more resource-demanding) task. Similarly, in a previous study including 7-year-old children, the prediction-advantage emerged only in the categorical task (Cottini et al., 2018). Moreover, slower OT RTs accompanied this prediction-advantage, but in contrast to Rummel and colleagues' study, the two groups did not differ in OT RTs on the specific PM task. Although replicating the adult findings partially, it is likely that the specific PM task used previously was too simple, given that accuracy rates were almost at ceiling.

For this reason, in the present investigation we adopted a similar PM task to that used in Cottini and colleagues' study, but this time increasing difficulty by including a higher number of specific cues. We hypothesized that this would not change the pattern of results, expecting no differences in PM performance between children with or without predictions. Moreover, we anticipated that children would be relatively accurate in their performance predictions (Cottini et al., 2018; Kvavilashvili & Ford, 2014). However, it is likely that confidence judgments of performance predictions would be inaccurate, consistent with previous studies with adults (e.g., Meeks et al., 2007; Rummel et al., 2013). Conversely, we hypothesized that children would be relatively accurate in judging their PM performance after executing the task, in line with MM-RM research (e.g., Visé & Schneider, 2000). Similar to RM studies, it is also likely that a tendency of overestimating past PM performance would emerge. Nevertheless, postdictions were expected to be related to PM performance, and thus, to be more indicative of children's procedural MM. Furthermore, we anticipated that children would be able to report in simple words which strategy, if any, they used to remember the PM task, and also those children using more active strategies would have higher PM performance than those relying on spontaneous processes. Finally, as shown in previous studies, EFs such as inhibitory control, WM and switching as well as declarative MM, are expected to be linked to PM performance (Cottini et al., 2018; Mahy, Moses et al., 2014a).

6.2. Method

6.2.1. Participants

The present study included 63 children (29 girls) aged between 7.33 and 8.67 years (*M* = 7.80, *SD* = 0.30). Children were recruited in different public primary schools of Northern Italy. All of them regularly attended the second grade of the primary school and were either native Italian speakers or adequately fluent in Italian. None had any neurological problem. Children and their legal caretakers gave oral and written consent (respectively) for participation.

6.2.2. Materials and procedures

Prospective memory paradigm

Event-based PM was evaluated using a computerized semi-ecological picture-classification task used in a previous study (Cottini et al., 2018), based on the classic experimental PM paradigm (Einstein & McDaniel, 1990). The task was designed and run by means of the SuperLab 4.5 Software. The task consisted of a total of 120 colored real-object photographs (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010). From 120 easy-to-name pictures, 115 were used for the OT and five were used for the PM task. The pictures used for the OT were divided into five categories (i.e., kitchen utensils and food, bathroom items, toys, school materials and clothes) represented by five corresponding rooms of a house (i.e., kitchen, bathroom, child's room, study room and wardrobe, respectively). The OT was divided into five blocks represented by the rooms. Each block began with a picture and the name of the room, and contained 24 pictures, presented sequentially, one by one, in the center of the screen. Each stimulus was presented on a white background (for 5000 ms), preceded by a fixation cross (500 ms), and followed by a blank screen (250 ms). Participants were required to decide for each stimulus whether it was part of the current block (category) or not, by pressing “yes” (S key) or “no” (L key) on the keyboard. From the 24 trials in each block, 12 were target trials, 11 were non-target trials and one was a PM cue. A total of five PM cues were embedded within the OT and were presented randomly across participants but always in the same position (i.e., every 22 trials).

Instructions for the task were given in the context of an illustrated story appearing on the computer screen. The purpose was to use a motivating and ecologically valid task, including real-object photographs and replicating an everyday setting, like tidying up the house (OT) and preparing the backpack for a school trip (PM task). The story was about a boy named Karl and his dog. Every time Karl’s dog enters the house, he turns it into a mess and Karl has to tidy it up. Participants were told that Karl needed help to put everything in the right rooms again as fast as possible, before his mother came back home. Thus, participants were instructed to press the “yes” key whenever an object belonged to the current room, and the “no” key when it did not. After performing a practice block, the story continued with Karl announcing that he has forgotten to prepare his backpack for the forthcoming school trip. Participants were asked to help Karl remember to put missing objects in his backpack (i.e., sandwich, water bottle, apple, umbrella and candy). For the PM targets, participants had to press the spacebar instead of pressing the “yes” or “no” keys. After receiving PM instructions, children were asked to repeat them in their own words, in order to ensure task procedure comprehension. Afterwards, a filler-task was introduced. Participants were told that Karl needed help to finish his homework before tidying up the house. This task consisted of the spatial reasoning sub-scale of the Primary Mental Abilities (Thurstone & Thurstone, 1981; see related section below) and lasted about 5 minutes. Subsequently, children had to perform the picture classification task, without instructions being repeated. Children, who never pressed the spacebar when a PM target appeared, were required to answer a series of questions.

These were aimed at examining whether children's PM failure was caused by a misinterpretation or by the incapability of remembering PM instructions (Kvavilashvili & Ford, 2014): (1) "Was there something else to do during the task besides tidying up the rooms?"; (2) "Was there something else to do whenever particular pictures appeared?"; (3) "Was there something to do when the picture of a sandwich, a water bottle, an apple, an umbrella or a candy appeared?"; and (4), "Didn't you have to press the spacebar whenever one of those pictures appeared?" (Cottini et al., 2018; Kvavilashvili & Ford, 2014). Children who could not respond to the last question were excluded from analysis, since their lack of responses to PM targets was probably due to forgetting/misunderstanding the instructions, rather than a PM difficulty (Kvavilashvili, Kyle, & Messer, 2008).

Procedural Metamemory

Performance predictions. To evaluate procedural MM we used a similar paradigm adopted in previous studies (Cottini et al., 2018; Kvavilashvili & Ford, 2014). After receiving task instructions and repeating them in their own words, half of the children were asked to predict whether they would remember the PM task or not. Here, the experimenter read aloud the following question which appeared on the screen: "Will you remember to press the spacebar whenever one of the five objects appears on the screen in order to put them in Karl's backpack?". After responding by pressing the "yes" or "no" key, a confidence rating scale was presented on the computer screen. Participants were asked how confident they were about their prediction: "How sure are you that you will remember/forget them?". Subsequently they had to estimate their own prediction on the scale, by pressing one of the following keys on the keyboard; "1" (*not sure at all*), "2" (*not sure*), "3" (*sure*) or "4" (*very sure*). The confidence rating scale was represented using four emoticons, ranging from very sad (*not sure at all*) to very happy (*very sure*), each with the written label underneath.

Postdictions. After performing the picture classification task, all participants were asked to evaluate their own PM performance. For this purpose, the experimenter read aloud the following question appearing on the computer screen: “Did you remember to press the spacebar whenever one of the five objects appeared on the screen?”. After responding by pressing the “yes” or “no” key, the same confidence rating scale as in the prediction phase (see related section above) appeared on the screen, accompanied by the following question: “How sure are you that you remembered/forgot?”. Children had to judge the confidence of the own postdiction on the rating scale, by pressing either the keys “1” (*not sure at all*), “2” (*not sure*), “3” (*sure*) or “4” (*very sure*), again represented by emoticons from very sad to very happy. Finally, participants had to give specific performance judgments, being asked how many objects they put in the backpack: “How many objects did you put in Karl’s backpack?”.

Strategies. After judging PM performance, children were asked whether they did anything to remember to press the spacebar whenever the cues appeared on the screen and if so, to report exactly what they did: (1) “Did you do anything to remember to press the spacebar to put the objects in Karl’s backpack?”; and (2) “What did you do?”. For children’s subjective reports, the following scoring points were assigned to reflect efficacy of the strategy used, in addition to the child’s insight and ability in explicit report: a score of 0 was assigned to children who said they did not do anything to remember or they totally forgot to think about the PM task; 1 point was assigned to those having little insight into their memory and not being able to report an explicit strategy (e.g., “I remembered only some of them and then I forgot them”); a score of 2 was assigned to those using a passive strategy and having some insight (e.g., “I recognized the objects whenever they appeared on the screen and pressed the spacebar”); 3 points were given to the children who used an active strategy implicitly (e.g., “I had the objects in my mind”); and 4 points were assigned to those who used an active strategy explicitly (e.g., “I continuously repeated the items in my mind”).

Declarative Metamemory

To evaluate declarative MM, we adopted a story task investigating children's knowledge about memory (Cornoldi et al., 1991). The original story task was slightly revised to include additional measures exploring MM knowledge related to PM (Cottini et al., 2018). Specifically, the story (entitled "The Captive Princess") was about a prince who wanted to save a princess captured in a castle. The story task consisted of different sections, after which children were asked questions exploring their *knowledge of forgetting* (e.g., "Will the prince remember what to do to save the princess?" and "Unfortunately, the prince could not remember the antidote. Why do you think he could not remember?"); *knowledge of retrieval* (e.g., "What can the prince do to retrieve the antidote?"); and *knowledge of storage* (e.g., "What can the prince do to be sure to remember the antidote this time?"). Children's answers were evaluated for their level of understanding and awareness of memory processes, in addition to their knowledge about memory strategies (see Cornoldi et al., 1991; see also Cottini et al., 2018).

Verbal and non-verbal abilities

Verbal abilities were evaluated by means of the *verbal meaning subscale* of the *Primary Mental abilities* (PMA; Thurstone & Thurstone, 1981). This paper-pencil task included a total of 30 words. For each word, participants had to select the appropriate synonym out of four possible alternatives. Each correct response was scored with one point.

Non-verbal abilities were assessed by means of the *spatial reasoning subscale* belonging to the *Primary Mental abilities* (Thurstone & Thurstone, 1981). This paper-pencil task included a total of 27 geometrical shapes. Each shape had to be completed with the appropriate twin-part in order to form a square, with participants selecting one twin-part out of four possible alternatives. Each correct response was scored with one point.

Verbal working memory

Digit span forward. Passive verbal WM storage (WM) was evaluated by asking children to repeat lists of numbers in the same presentation order. Digits were presented one per second and lists, beginning with three items, increased by one unit whenever the participants correctly repeated at least two of three lists of the same length. There was no time limit and the final score was represented by the length of the last correctly-repeated digit list.

Digit span backward. Active verbal WM (WM) was evaluated by asking children to repeat lists of digits in the reversed presentation order. As for the previous test, numbers in each list were presented one per second beginning with the shortest series and increasing gradually of one unit (see section above regarding "digit span forward").

Inhibitory control

The Go/No-Go paradigm was adopted to evaluate children's inhibitory control abilities (see Brocki & Bohlin, 2004). This was computerized and run with the SuperLab Software. A total of 50 Go- and No/Go-stimuli (yellow and blue ball, respectively) were shown individually, randomly in the center of the screen. A habitual response was elicited by presenting more Go-trials (75%) than No-Go. Each trial consisted of a fixation cross (250 ms), a Go- or a No-Go stimulus presented on a black background for a maximum of 500 ms, and a blank screen presented for a randomly variable interval, ranging from 2550 ms to 2783 ms. Whenever a Go stimulus was presented, children were asked to press the spacebar as fast as possible, whereas they were instructed to suppress response whenever a No-Go stimulus appeared. The number of commission errors (i.e., erroneously pressing the spacebar to a No-Go stimulus), were considered as a direct measure of inhibitory control, whereas the number of omission errors (i.e., omitting response to a Go stimulus) indicated inattention.

Switching

Visually cued color-shape task (Zelazo, Craik, & Booth, 2004). This computerized task consisted in the sequential presentation of a total of 50 colored shapes. Children were instructed to classify each presented figure by either its shape or color, depending on the presentation of the word "color" or "shape" simultaneously. Participants had to respond to each trial as fast and accurately as possible, by pressing one of four buttons on the keyboard (green circle, red triangle, blue square and yellow diamond). Figures were randomly presented across participants and were a combination of the four possible shapes and colors. Each colored shape was presented on the center of the screen on a white background, until a response was given. Number of switching errors (e.g., responding considering the color instead of the shape when a shape-response is requested) as well as switching costs (i.e., the mean RTs on the trials after a switch-trial) represented children's switching ability.

6.2.3. Data analysis

Statistical analyses were similar to those used in Cottini and colleagues (2018), conducted with the free statistical software R (R Core Team, 2016). First, children's mean age, gender and mean values at the different tests were calculated separately for the prediction and the non-prediction group. Second, s series of chi-square analyses were conducted to compare participants' performance predictions and postdictions with their actual PM performance. Third, four mixed effects regression models (Pinheiro & Bates, 2000) were conducted to evaluate the effects of performance predictions, strategy use and control measures on PM and OT performance (accuracies and RTs). Each model included the following fixed factors: group, declarative MM, WM span forward and backward, inhibition, switching and verbal abilities (PMA-V). Mixed effects regression models were fit adopting the lme4 package (Bates, Maechler, Bolker, & Walker, 2014).

Children's OT and PM task accuracies were included as dependent variables within the OT and PM task model fitted for accuracy, respectively. Since OT accuracy was a dichotomous variable, logit transformation was adapted on the data within a generalized mixed model (Jaeger, 2008). The nine included fixed effects were: the two-level factor group (Group0 = without predictions and Group1 = with predictions), the four-level factor strategy (Strategy0 = no strategy, to Strategy4 = explicit active strategy), the Group × Strategy interaction, declarative MM, WM span forward and backward, commission errors in the Go/No-Go task (i.e., inhibition errors) and switching errors in the Color/Shape task. These predictors were either scaled or log-transformed in order to reduce data skewness. The interactions between group and these six factors were added as continuous fixed-effects predictors. The ordinal position of every single trial within the experiment (i.e., trial number), was also added as a covariate. The effects of the different stimuli within the task, as well as of participants were included as random effects, to increase statistical power by controlling a possible source of variance. First, we performed an initial model including the three fixed effects (Group, Strategy, Group × Strategy interaction) and the two random effects (Stimuli and Participants). Second, if the model converged, a forward-fitting procedure was performed (as typically done with the "glmer" function), that is, the fixed effects predictors were added to the model one by one. If the model converged the predictor was kept, otherwise it was removed. The final model was obtained after examining significance of each predictor.

Log-transformed RTs for correct responses only were considered as dependent variables within the two models fitted for OT and PM task RTs separately. Besides the fixed effects included in the models for accuracies (Group, Strategy, Group × Strategy interaction, declarative MM, WM span forward and backward, inhibition errors in the Go/No-Go task, switching in the Color/Shape task, and interaction between Group and the last five variables), the factors trial number and preceding trial (that is, the RT to the stimulus presented before the current one) were added as covariates. Moreover, the two models for RTs included the same random effects as in the two models for accuracy. Similarly, all the variables were added in the initial model, adopting the automatic backfitting procedure "step" (lmerTest package version 2.0 − 33: Kuznetsova, Brockhoff, & Christensen, 2015). Consequently, non-significant factors were excluded one by one, beginning from the factor presenting the smallest |t| value. Thus, the final model included only significant effects.

The four resulting models are presented in Tables 8 and 9. The fixed effects can be interpreted as those of classical regressions. The impact of each fixed effect is determined partialing out the effect of the remaining significant fixed effects. If a main effect resulted to be part of a significant interaction, it was maintained in the analysis despite of being significant or not.

6.3. Results

6.3.1. Descriptive statistics

Means and standard deviations relative to participant's age and scores on the various cognitive measures are shown in Table 5. All the scores of the two groups (with and without predictions) were compared performing a multivariate analysis of variance (MANOVA). Results showed that the two groups did not differ significantly: $F(12, 50) = 1.862$, $p = .942$; Pillai's trace = 0.309, $\eta^2_p = .06$. Children in the two groups were also equivalent for age ($p = .79$, $\eta^2_p < .01$), verbal abilities ($p = .133$, $\eta^2_p = .04$), non-verbal abilities ($p = .873$, $\eta^2_p < .01$), inhibitory control ($p = .54$, $\eta^2_p = .01$), switching ($p = .77$, $\eta^2_p < .01$), digit span forward ($p = .418$, $\eta^2_p = .01$), digit span backward ($p = .041$, $\eta^2_p = .07$), declarative MM relative to knowledge of forgetting ($p = .081$, $\eta^2_p = .05$), knowledge of storage ($p = .416$, $\eta^2_p = .01$), knowledge of retrieval ($p = .084$, $\eta^2_p = .05$), and total MM score ($p = .025$, $\eta^2_p = .08$).

Table 5

Means (and standard deviations) of raw scores at the various tests included in this study.

	Non-prediction group (n = 31)	**Prediction group** (n = 32)	**Actual range**
Age (in years)	7.81 (0.34)	7.79 (0.25)	–
Gender	M = 14; F = 17	M = 20; F = 12	–
Cognitive Measures			
PMA verbal abilities	26.35 (1.84)	25.50 (2.55)	0–30
PMA non-verbal abilities	13.87 (4.06)	14.03 (3.90)	0–27
Inhibitory control (errors)	2.12 (2.00)	1.87 (1.66)	–
Switching (errors)	4.48 (1.82)	4.34 (1.89)	–
Digit Span forward	4.52 (0.51)	4.41 (0.56)	–
Digit Span backward	2.81 (0.60)	3.16 (0.72)	–
Declarative MM story task			
Knowledge of forgetting	7.32 (0.33)	6.50 (0.33)	0–14
Knowledge of storage	3.94 (0.08)	3.84 (0.08)	0–4
Knowledge of retrieval	1.77 (0.14)	1.44 (0.13)	0–4
Declarative MM total	13.03 (2.29)	11.78 (2.03)	0–22

Note. M, male; F, female; PMA, Primary Mental abilities; MM, metamemory.

6.3.2. Procedural metamemory and prospective memory performance

To evaluate the relation between procedural MM and PM, we considered children's performance predictions and postdictions for PM performance (see Table 6) as well as strategy use. All 63 children remembered instructions for the PM task at the end of the procedure, indicating that PM errors were due to PM difficulties, rather than RM difficulties (Kvavilashvili et al., 2008). Thus, they were all included in the following analyses. For performance predictions, only children who were in the prediction group were considered, whereas all children were considered within analyses concerning postdictions and strategy use. Out of 63 participants, 43 (73%) remembered to execute the PM task at least once. Mean proportion of correct PM responses was 0.41 (*SD* = 0.30).

Performance predictions and confidence judgments. Out of 32 children who were asked to predict their PM performance, all predicted remembering the PM task (see Table 6). Twenty-two children (69%) were "sure", nine were "very sure", and one child was "not sure" of their own prediction. In total, 24 children (75%) effectively remembered to press the spacebar correctly, at least once when a PM cue appeared, showing that they were fairly accurate in predicting the direction of their actual performance. Of the 22 children who were sure of remembering, 17 (77.3%) effectively remembered to perform the PM task at least one time, whereas of those nine who were very sure, six (66.7%) effectively remembered. The child who was not sure of his prediction actually remembered the PM task. Chi square analysis showed that confidence judgments of predictions were not significantly related to actual PM performance, X^2 (2, $N = 32$) = 0.73, $p =$ .70.

General postdictions and confidence judgments. Of 63 children, 46 (73%) effectively remembered to perform the PM task at least once (see Table 2). However, postdictions were considered for 51 children only, because responses were either incomplete or missing. Of those children, 12 reported that they forgot to perform the PM task and 39 reported that they had remembered it. Of those who reported forgetting, five actually forgot to perform the PM task, whereas seven responded to at least one PM cue. Of 39 children who reported remembering, all effectively remembered the PM task at least once. Chi square analysis revealed that the relation between postdiction and actual PM performance was significant, indicating that generally, children had good insight in their past PM performance, X^2 (1, $N = 51$) = 18.02, $p < .001$. Concerning confidence judgments, of 12 children who reported forgetting, eight were sure, one was not sure and one was very sure of the given judgment. However, children who reported remembering were mainly very sure of their judgment ($N = 28$; 71.8%), with fewer indicating sure ($N = 9$; 23.1%) and only two being not sure ($N = 2$; 5.1%). Overall, those who reported remembering were highly confident in their judgment, whereas those who reported forgetting, were less confident. Chi square analysis confirmed these data, showing that subjective responses were significantly related to the actual performance, X^2 (1, N = 49) = 12.88, p = .002. Moreover, children who were very sure of their success in the PM task were very accurate in their judgments, since all remembered to perform it (100%). Similarly, those who were sure in most cases effectively remembered the task (82.4%), whereas those three who were not sure of their judgment had little insight into their past performance, since they had actually remembered the PM task. Again, this pattern of results was confirmed by chi square analysis, X^2 (2, N = 49) = 6.02, p < .05.

Table 6

Confidence judgments of predictions and postdictions for prediction- and non-prediction groups, by number of remembered prospective memory cues.

Group	**Prediction Confidence**	**Total**	**Remembered**					
			0	**1**	**2**	**3**	**4**	**5**
Prediction group	Not sure	1	0	1	0	0	0	0
	Sure	22	5	1	6	5	3	2
	Very sure	9	3	1	2	3	0	0
	Postdiction Confidence							
Prediction group	Sure	8	1	0	6	0	1	0
	Very sure	15	0	1	0	9	5	0
Non-prediction group	Not sure	3	0	1	2	0	0	0
	Sure	9	2	2	2	2	1	0
	Very sure	14	0	0	4	6	2	2

Specific postdictions on the number of remembered cues. Finally, we asked children to report the number of correct PM responses, that is, to judge how many times they correctly pressed the spacebar on a PM cue. The majority of the children (N = 29) overestimated past PM performance, reporting a higher number of identified PM cues than actually remembered, whereas 20 children reported an accurate number of cues. Chi square analysis showed that children's responses were related to actual PM performance, X^2 (2, N = 49) = 87.46, p < .001. In both groups, the number of reported PM hits was higher than real performance (see Figure 6): t(22) = 3.314, p = .005, for the non-prediction group (M = 0.70; SD = 1.06), and $t(25) = 6.59$, $p < .001$, for the prediction group (M = 1.42; SD = 1.10).

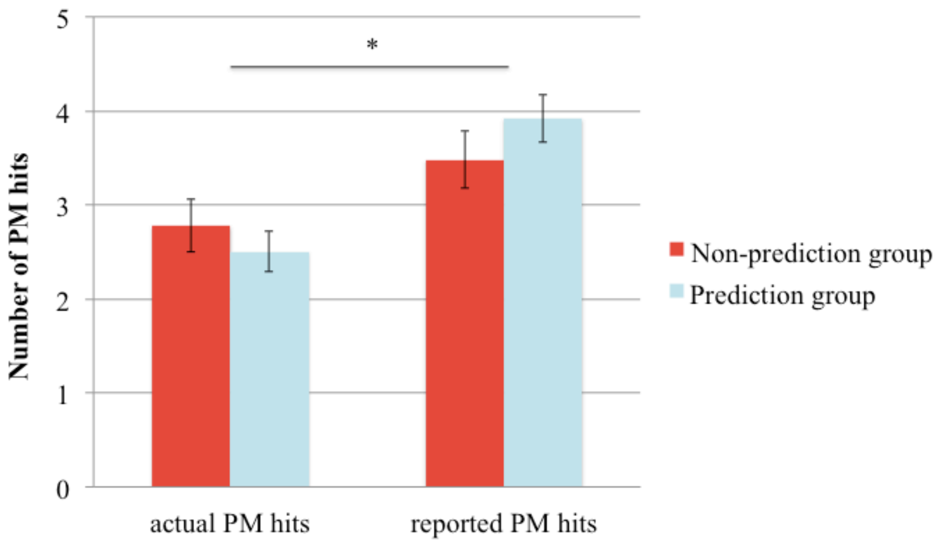

Figure 6. Comparison between actual and reported PM hits for prediction and non-prediction groups. Error bars represent standard errors from the mean.

Strategy. Of the 63 children, 17 did not use any strategy, mainly reporting that they completely forgot to think about the PM task. Of these, one child actually remembered the PM task in any event (see Table 7). Five children reported that they thought about the PM task at the beginning, and that they did not think about it subsequently. However, all of these in fact remembered to respond to at least one PM cue. Eleven children reported remembering the PM task whenever they encountered a PM cue on screen, suggesting reliance on automatic retrieval processes. Ten children said that they always kept the PM cues in mind and 19 reported continuous repetition in their mind, while performing the OT. The relation between the strategy used and PM performance was significant, X^2 (4, N = 63) = 58.21, $p < .001$. In addition, the relation between used strategy and PM performance was significant when only considering children who correctly performed the PM task at least once, X^2 (16, N = 51) = 23.39, p = .02.

Table 7

Reported strategies used to remember the prospective memory task by number of remembered prospective memory cues.

Strategy used	Total	Remembered					
		0	1	2	3	4	5
No strategy	18	17	1	0	0	0	0
Unclear strategy	5	0	1	4	0	0	0
Passive retrieval	11	0	0	3	6	1	1
Implicit active strategy	10	0	2	2	2	4	0
Explicit active strategy	19	0	0	5	9	4	1

Note. Strategy0, no strategy used; Strategy1, unclear strategy; Strategy2, passive; Strategy3, active but not explicit; Strategy4, active and explicit.

6.3.4. Prospective memory and ongoing task performance

Ongoing task performance. Models for OT performance converged only for RTs, showing that children who reported using a more active strategy, had slower OT RTs than children using a passive or no strategy (see Table 8). Switching costs were negatively related to OT RTs; those children with reduced switching costs were slower in the OT than those with higher switching costs. The covariates of preceding trial and participants were both significant, and thus removed. Random effects of stimuli and participants indicated significant variability in the overall performance of each participant, and between the stimuli. This indicates that considering these sources of variance improves the model's goodness of fit. This is particularly important, given other variables of inhibition, verbal ability, declarative MM, WM span forward and backward were excluded during the backfitting procedure, and can not be considered as relevant predictors in the present analysis. The effect size for the model of OT RT was r^2 = .29.

Table 8

Mixed-effects regression model for ongoing task performance.

Fixed effect parameters	Accuracy			Response times		
	β (*SE*)	*z*	*p*	*β* (*SE*)	*t*	*p*
Intercept	3.528 (0.191)	18.429	<.001	6.593 (0.098)	67.17	<.001
Group0, Strategy0						
Group1 = with predictions	−0.292 (0.153)	−1.909	=.056	−0.003 (0.039)	−0.09	n.s.
Strategy			n.s.	0.075 (0.006)	2.52	<.05
Switching costs			n.s.	0.036 (0.011)	−3.21	<.01
Log(Preceding Trial)	/			0.147 (0.012)	11.80	<.001
Participants	/			−0.017 (0.007)	−2.15	<.05
Random effect Parameters	*SD*			*SD*		
Random effect Stimuli	1.193			0.089		
Random effect Participants	0.453			0.077		
Residuals				0.225		

Note: The model for the OT accuracy was calculated considering all responses (correct and incorrect ones) through this formula: glmer(Accuracy ~ Group*Strategy + scale(Trial Number) + (1 | Stimuli) + (1 | Participants), data = Ongoing_accuracies, family="binomial"). The model for OT RTs was calculated considering the correct responses only, through this formula: lmer(log(Ongoing_RTs) ~ Group*Strategy + Strategy*scale(SwitchCosts_shape) + scale(Trial Number) + log(Preceding Trial) + (1 | Stimuli) + (1 | Participant), data = Ongoing_RTs).

Prospective memory performance. For PM performance, models converged for accuracy and RTs (see Table 9). For PM accuracy, the effect of group was not significant, whereas the effect of strategy was. Children who used a more active strategy, remembered significantly more PM cues than children relying more on automatic processes. None of the other fixed effects reached the significance threshold. Effect size for the model for PM accuracy was $r^2 = .28$.

For PM RTs, the effect of group was significant, showing that children in the prediction group had faster RTs when responding to PM cues. The significant Group x Strategy interaction indicates that group difference were probably due to strategy use. The effect size of the model for PM RT was $r^2 = .12$.

Table 9

Mixed-effects regression model for prospective memory performance.

Fixed effect parameters	Accuracy			Response times		
	β (*SE*)	*z*	*p*	*β* (*SE*)	*t*	*p*
Intercept	−2.624 (0.546)	−4.96	<.001	7.568 (0.411)	18.40	<.001
Group0, Strategy0						
Group1 = with predictions	0.395 (0.310)	1.28	n.s.	−0.336 (0.169)	−1.99	<.05
Strategy	0.764 (0.132)	5.79	<.001			n.s.
Switching (accuracy)	−0.343 (0.203)	1.69	=.09			n.s.
Group1 × Strategy	/			0.107 (0.052)	2.05	<.05
Random effect Parameters	*SD*			*SD*		
Random effect of Stimuli	0.326			0.00		
Random effect of Participants	0.332			0.00		
Residuals				0.251		

Note. The model for the PM accuracy was calculated considering all responses (correct and incorrect ones) through this formula: glmer(Accuracy ~ Group + scale(Accuracy_colorshape) + scale(SwitchCosts_shape) + (1 | Stimuli) + (1 | Participants), data = Prospective_accuracies, family="binomial"). The model for PM RTs was calculated considering the correct responses only, through this formula: lmer(log(RTs) ~ Group*Strategy + scale(SwitchCosts_shape) + log(Declarative_MM) + (1 | Participant), data = Prospective_RTs.

6.4. Discussion

The main purpose of the present investigation was to examine the link between procedural MM and PM in children aged between 7 and 8 years. Specifically, we were interested in studying children’s abilities to judge their own PM performance before (predictions) and after (postdictions) performing a PM task, comprising five specific cues. In addition, we collected children’s reports of the strategy they used to perform the PM task. A further aim was to explore whether performance predictions could influence PM performance on a task using specific PM cues. Consequently, we compared two groups, with and without PM performance predictions. In a previous study, performance predictions have been shown to improve performance on a PM task with categorical cues, but not specific cues (Cottini et al., 2018). However, performance on the specific PM task was near ceiling, thus, in the present study the number of specific cues was increased. Finally, we aimed to examine the role of declarative MM and EFs in children's PM.

As expected, PM performance did not differ across groups (with or without predictions). In both groups, accuracy rates were around 41%, neither close to floor nor ceiling level. Children's OT accuracy and RTs in the two groups were also similar, showing that making performance predictions did not affect strategic monitoring processes. This is in line with the pattern of results related to the specific PM task in a previous study (Cottini et al., 2018). Contrary to Rummel and colleagues' study with adults (2013), our results did not reveal a prediction-induced OT performance slowing on the specific PM task. Given the high number of PM cues in the present task, it is likely that the perceived difficulty of the task, that is, the expected task demands, might have influenced children's attention-allocation strategies in both groups (cf. Rummel & Meiser, 2013). In fact, irrespective of group, participants' PM performance was positively related to the strategy used to remember the PM task. Children using an active strategy (e.g., repeating continuously PM cues and searching for them) remembered significantly more PM cues than those who relied more on automatic or ineffective processes (e.g., "I recognized them when I saw them on the screen"). Children adopting an active strategy also had significantly slower OT RTs, suggesting that they strategically monitored for PM targets.

Similar to earlier studies (Cottini et al., 2018; Kvavilashvili & Ford, 2014), 75% of children in the prediction group made an accurate prediction, predicting they would remember the PM task and actually remembering it. However, as in Cottini and colleagues study (2018), all the children predicted they would remember the PM task, suggesting that predictions were influenced by other factors, potentially independent of MM abilities (e.g., wishful thinking hypothesis; see Schneider, 2015). Moreover, confidence judgments of predictions were not related to actual PM performance, suggesting that performance predictions may not be considered as a pure MM measure. For this reason, in the present study a postdiction paradigm has also been included. In RM research, postdictions have been seen to be a better measure of procedural MM (see Schneider, 2015). As expected, children's performance judgments after the PM task were fairly accurate, with 86% of children accurately reporting whether they forgot/remembered PM task performance.

Similarly, confidence judgments were very accurate too; for example, with those for who were "very sure" of having remembered the PM task, having a high accuracy rate. This is in line with RM research showing that children at this age are relatively able to give accurate judgments of past memory performance (e.g., Visé & Schneider, 2000). However, data on children's specific postdictions, related to the number of remembered PM cues, showed that children overestimated their specific performance overall, with 60% reporting they remembered more than they actually did. Conversely, 40% of the children were accurate in reporting the number of remembered PM cues, and no child underestimated PM performance. To date, there is only one study which has examined adults' procedural MM alongside a PM task by including a postdiction-paradigm (Meeks et al., 2007). Consistent with RM research, adults' results showed that they tended to underestimate their previous PM performance.

Finally, our study failed to replicate previous studies or to confirm our hypothesis on the role of EFs and declarative MM in children's PM. The resulting models for PM performance did not reveal any significant contribution of either EFs or declarative MM. However, switching abilities predicted OT RTs, showing that the children who were better in the switching task were slower on the OT. This may indicate that those children engaged more in strategic monitoring (Smith, 2003; Smith & Bayen, 2004). Similarly, in an earlier study (Cottini et al., 2018), inhibitory control abilities appeared to be relevant for OT performance, suggesting that EFs may be involved particularly when the OT has to be interrupted and resources switched to the PM task (see Mahy et al., 2014). On the other hand, declarative MM was not related to performance on the present PM task. This lack of effect may be due to the relatively small sample size and/or to the number of variables included in the present analyses. However, it could also be due to the strong predictive effect of the strategy variable. Results suggested that children reporting continuously repetition and search for the PM cues, also attained significantly higher PM performance than children using a more passive strategy (or those aware of using a strategy). At the same time, the children using an active strategy had significantly slower OT RTs. As argued by Meeks and colleagues (2007), MM awareness of personal PM abilities related to perceived task difficulty is likely to influence engagement of attentional monitoring processes. This may also indicate that children who reported using an active strategy (and with a high PM performance) had good insight into their own PM ability. In fact, being able to use an effective strategy and being conscious of its use, is indicative of having good MM (see Schneider, 2015). However, as only about half our sample reported an active strategy to remember the PM task, this suggests PM ability may still be developing at this age. In fact, RM studies demonstrate the relation between knowing about memory processes and applying that knowledge develops around (but not before) the age of 7 and 8 years (Lockl & Schneider, 2003).

6.4.1. Summary and conclusions

The present study has shown that performance predictions did not influence subsequent performance on a specific PM task. This was consistent with previous studies, showing that making predictions can affect performance on a categorical, but not a specific PM task (Cottini et al., 2018; Meier et al., 2011; Rummel et al., 2013). Similarly, children were relatively able to predict the direction of their future outcomes (Cottini et al., 2018; Kvavilashvili & Ford, 2014). However, their confidence judgments were fairly imprecise and not related to PM performance. However, children's general postdictions were highly accurate and precise compared to their actual PM performance. That said, when probing specific number of remembered PM cues, children largely overestimated past PM performance. Furthermore, about half of the children reported using an active strategy to remember the PM task, whereas the other half relied on automatic processes or did not use any strategy. The latter half performed significantly more poorly than those reporting active strategy use. Report of using an active strategy was related not only to better PM performance, but also slower OT RTs, suggesting that MM awareness influenced engagement of attentional monitoring processes.

To our knowledge, this is the first investigation examining procedural MM in PM of school-aged children, by 1) adopting a prediction-postdiction paradigm in association with a PM task, and 2) by including self-reports on strategy use. Recent studies on both adults and children have shown that MM plays an important role in PM (e.g., Cottini et al., 2018; Kvavilashvili & Ford, 2014; Rummel et al., 2013; Rummel & Meiser, 2013; Schnitzspahn et al., 2011). However, evidence is still scarce and inconsistent. The present study clearly contributes to better understanding of the role of MM in engagement of strategic monitoring processes often involved in prospective remembering (McDaniel, Umanath, Einstein, & Waldum, 2015). Moreover, these results indicate that even school-aged children can have good insight into their PM ability, and relatively capable (and aware of) applying effective strategies to improve PM performance. Consequently, assessing MM in relation to PM can be a valuable method to understand the processes underlying PM performance better, especially in childhood.

Future studies should include different age groups in order to define the developmental trajectory of MM awareness for PM processes. Furthermore, it would be ideal to avoid use of the classic performance prediction paradigm together with a PM task, given its frequently inconsistent results and potential influence on performance itself. Instead, it would be interesting to investigate children's general beliefs about their memory functioning and memory self-efficacy (e.g., McDonald-Miszczak, Gould, & Tychynski, 1999), as well as anticipated task demands (e.g., Rummel & Meiser, 2013). This may shed light on the manifold cognitive processes contributing to PM development during childhood. Moreover, it may be helpful in designing efficient educational programs to reflect and support children's everyday memory abilities.

7. Study 3: The Longitudinal Development of Prospective Memory and Metamemory in School-aged Children

7.1. Introduction

Prospective memory (PM) refers to the ability to remember to realize a previously planned intention (Einstein & McDaniel, 1990), such as remembering to send a letter when passing by the post office (i.e., event-based), to feed our goldfish (i.e., habitual), to take something out of the oven after half an hour (i.e., time-based), or to make a phone call after a lesson (i.e., activity-based). PM is a critical and pervasive ability in everyday life, which determines not only our independence from others but also our success in various contexts and across the entire lifespan (e.g., in school, work and social relationships). For instance, PM is particularly important during the primary school years when environmental demands increase. Children at this age are expected to become more and more independent from adults and to be able to realize at least some of their personal plans as well as teachers' and parents' assignments (see Mahy, Moses, & Kliegel, 2014a). In fact, the ability to remember to fulfill previously planned actions develops considerably during these years (Kerns, 2000; Kliegel, Mahy, Voigt, Henry, Rendell, & Aberle, 2013; Smith, Bayen, & Martin, 2010; Yang, Chan, & Shum, 2011).

Research investigating the developmental trajectory of PM in children has shown that PM performance improves especially between 7 and 8 years of age, being strongly linked to age-related improvements of executive functions (EFs; Spiess, Meier, & Roebers, 2016; Yang, Chan, & Shum, 2011). Moreover, recent studies have suggested that metamemory (MM) would probably play an important role in the development of PM during childhood (Cottini, Basso, & Palladino, 2018; Kvavilashvili & Ford, 2014). However, there is no study which has explored the developmental relationships between those processes during childhood (although see Spiess et al., 2016). The purpose of the present investigation was to examine the longitudinal development of MM, event-based PM, and EFs, as well as their relationships in school-aged children.

7.1.1. The development of prospective memory in school-aged children and the importance of executive functions

Event-based PM is typically assessed in laboratory-based experiments by asking participants to perform an ongoing task (OT; e.g., computerized lexical decision task), and to concurrently remember to execute a specific action whenever a previously defined cue appears (e.g., pressing the spacebar whenever an animal word appears). PM performance has shown to improve considerably from childhood until late adolescence, while it declines in older age (Zimmermann & Meier, 2006; 2010). Developmental research on PM in children has identified a critical change in PM performance around 7 and 8 years of age (e.g., Kerns, 2000; Smith et al., 2010; Yang et al., 2011). Executive functions (EFs), such as inhibitory control, working memory (WM), set shifting and monitoring, have been frequently shown to underlie these age-related improvements (e.g., Spiess et al., 2016; Yang et al., 2011; Smith et al., 2010). This has been revealed mainly in cross-sectional studies in which different age groups were compared on different PM tasks (e.g., Yang et al., 2011; Smith & al., 2010). For instance, Yang and colleagues (2011) found that inhibitory control and WM were significantly linked to age-related improvements of PM performance. Similarly, Kliegel and colleagues (2013) found that older children outperformed younger children especially in executive-demanding PM tasks. Moreover, recent lifespan studies revealed that compared to adults, children were less able to engage in strategic monitoring, probably because they have fewer cognitive resources than adults (see Cottini & Meier, in preparation; Kretschmer-Trendowicz & Altgassen, 2016; Smith et al., 2010). The link between PM and EFs has been further shown in a longitudinal study comparing children's performance between 7 and 8 years of age (Spiess et al., 2016). Here, EFs and PM performance at Time 1 were strongly related to developmental improvements at Time 2.

The important role of EFs in the development of PM during childhood has been recently summarized and theorized within an Executive Framework of PM development (Mahy, Moses et al., 2014a). Accordingly, progress in EFs should support PM, especially when a task is highly resource demanding. Moreover, the various components of EFs are likely to have a different impact on PM development at different ages as well as during the single phases of prospective remembering (i.e., encoding, retention, retrieval, execution, and evaluation). The authors claimed that inhibitory control, set shifting and monitoring should play a crucial role in PM during the school years, whereas WM would probably be more relevant in earlier years. Besides the important contribution of EFs, PM development would probably profit also from metamemory (MM). However, there are only few studies which have investigated this aspect in children (Cottini et al., 2018; Kvavilashvili & Ford, 2014) and there is any study to date examining their developmental relation (although see Spiess et al., 2016).

7.1.2. The relationship between prospective memory and metamemory in children

The term MM embraces both declarative and procedural knowledge about memory processes (Kreutzer, Leonard, Flavell, & Hagen, 1975). The first refers to the explicit knowledge and awareness about memory (i.e., declarative MM), and the second refers to the ability of using strategies, controlling, regulating and monitoring the own memory performance (i.e., procedural MM). Declarative MM is typically evaluated using interviews, questionnaires or story tasks (e.g., Cornoldi et al., 1991; Kreutzer et al., 1975), while procedural MM is measured by asking participants to judge memory performance prior, through or subsequent to a memory task (e.g., Roebers, Krebs, & Roderer, 2014; Roebers, von der Linden, Schneider, & Howie, 2007). The accuracy of these judgments indicates the level of insight in personal memory processes and seems to affect memory ability itself (see Schneider, 2015).

To date, procedural and declarative MM have been studied almost exclusively in relation to retrospective memory (RM) tasks. These have shown that MM develops considerably throughout the school years, with improvements in declarative MM being related to language and intellectual abilities, whereas changes in procedural MM seem to be linked to control and monitoring processes (e.g., Isingrini, Perrotin, & Souchay, 2008). The relation between knowing about memory and being able to efficiently apply that knowledge has shown to develop only later in childhood and to drive improvements in RM (Lockl & Schneider, 2003). Younger children might know which strategies can be used for a particular task, but they may be not able to translate that knowledge in an efficient action (e.g., Schneider & Pressley, 1997). Moreover, school-aged children have shown to be less accurate than adults in predicting, judging and monitoring memory performance, displaying a tendency to overestimate the own memory abilities.

Although there is a large body of research demonstrating the important role of MM in the development of RM, there are only few studies to date which have investigated MM in relation to children's PM (Cottini et al., 2018; Kvavilashvili & Ford, 2014). Kvavilashvili & Ford (2014), showed that procedural MM was significantly related to PM in 5-year-old children, being relatively accurate in their PM performance predictions. Similarly, in our previous study, 7-year-old children showed to be able to predict the trend of their future performance on a PM task, but they were rather imprecise when expressing their confidence (Cottini et al., 2018). Studies with adults, have frequently shown similar inconsistent results, with predictions not always being related to actual PM performance (e.g., Meeks, Hicks, & Marsh, 2007; Rummel et al., 2013). It has been argued that other factors may be involved in performance predictions which are not directly related to procedural MM, such as wishful thinking or task familiarity (Visé & Schneider, 2000).

Nevertheless, making predictions prior to a PM task has recently revealed to affect PM performance itself both in adults and in children (Cottini et al., 2018; Meier et al., 2011; Rummel et al., 2013). Participants who were asked to make predictions outperformed a control group on a resource-demanding PM task. Furthermore, this prediction-advantage was accompanied by a slowing of OT RTs, suggesting that making predictions has enhanced strategic monitoring (Cottini et al., 2018; Rummel et al., 2013). Similarly, in Meier and colleagues' study (2011), predictions significantly increased participants' probability to adopt a search strategy, functional for the successful detection of the PM targets.

7.1.3. The current study

The aim of the current investigation was to explore the developmental trajectory of children's PM within a longitudinal design. Developmental studies have shown that an important increase in PM performance occurs between 7 and 8 years of age (Kerns, 2000; Smith et al., 2010; Yang et al., 2011). The only longitudinal study to date has shown that PM development between 7 and 8 years of age is primarily supported by EFs. However, there is evidence that also MM is likely to drive age-related advances in PM, but there is no existing evidence to date which confirms this hypothesis (see Cottini et al., 2018). Consequently, we decided to compare children's PM performance between 7 and 8 years of age within a longitudinal study. Thus, the same children were tested two times on the same tasks, with a mean delay of 12 months between the first and the second administration. For PM we adopted the categorical and more resource-demanding PM task used in a previous study (Cottini et al., 2018). Moreover, we included the same performance prediction paradigm as well as the same measures of declarative MM, inhibitory control and WM used in that previous study. Additionally, we asked those children who remembered to perform the PM task, whether they searched for the PM targets or whether they recognized them when they appeared on the screen (see Meier et al., 2011).

First of all, we expected that children's performance would increase from Time 1 to Time 2 in each included measure. Moreover, we hypothesized that children's inhibitory control, WM and MM abilities would contribute to the developmental changes in PM. As in our previous study, the group with predictions was expected to outperform the group without predictions (see Cottini et al., 2018). We hypothesized that children in the prediction group would be able to predict the direction of their future PM performance both in Time 1 and Time 2. However, confidence judgments were expected to be unrelated to actual PM performance at Time 1. On the other hand, if prediction confidences were related to PM performance at Time 2, then we could assume that children's ability to judge the own PM performance has improved and that the performance prediction paradigm used in this study was reliable. In contrast, if MM judgments were again not related to the actual PM performance at Time 2, then it is likely that children's MM abilities were still scarce or rather that the performance prediction paradigm is not a suitable method to assess procedural MM in relation to PM. Finally, in adults, making performance predictions has shown not only to boost PM performance, but also to influence search experience (Meier et al., 2011). Strategic monitoring has shown to be particularly functional when performing a categorical PM task (Hicks, Marsh, & Cook, 2005). Consequently, we would ideally expect that those children who reported a search experience had also higher PM rate than children reporting the contrary, and that this would possibly influence PM performance itself. However, children at this age may not have reached yet the needed cognitive maturation permitting them to apply an appropriate memory strategy and to efficiently control and regulate memory performance (Lockl & Schneider, 2003). It is likely that they know which strategy to use and that they actually use it, but it is also probable that they do not have yet enough resources to use it appropriately.

7.2. Method

7.2.1. Participants

Fifty-nine children (33 girls and 26 boys) recruited in a public primary school in Northern Italy participated in the present study. Their mean age was 7.37 (*SD* = 0.27) years at Time 1, and 8.37 (*SD* = 0.27) at Time 2. All children were either native Italian speakers or sufficiently fluent in Italian. Parents and children provided written and oral authorization, respectively, for their participation to the present study. None of the children had neurological disorders.

7.2.2. Materials

Children were tested during the first quarter (November and December) of the second (Time 1) and the third (Time 2) grade of the primary school. Consequently, the delay between the first and the second data collection comprehended 12 months. The same tasks were used in Time 1 and Time 2. Trials within each task were presented in random order at Time 1 and Time 2.

Prospective memory paradigm

To evaluate event-based PM we adopted the picture-classification task including a categorical PM task used in Cottini et al. (2018). The task consisted of a total of 78 colored real-object photographs (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010), of which 75 were used for the picture classification (OT) and three were used for the PM task. PM cues belonged to the category "fruits" (i.e., apple, banana and strawberry). They were presented randomly but always on the same position (every 24 trials). Each trial was composed by of a fixation cross (250 ms), followed by a picture presented on the center of the computer screen (until a response was given or for a maximum of 5,000 ms), and a blank screen (500 ms). The pictures were divided in five blocks representing different rooms of a house (i.e., kitchen, bathroom, study room, wardrobe and kids room). Each block included a total of 15 trials and was preceded by the picture and the name of the room. For the OT, participants were required to decide whether each picture belonged to the current room or not by pressing the "yes" (S key) or "no" key (L key) respectively. In each block, half of the trials were part of the actual category and half were not. Whenever a PM cue appeared, participants were required to press the spacebar instead of pressing "yes" or "no" as for the OT.

Procedure was similar to that in Cottini and colleagues' study (2018). First, children were instructed for the OT and after performing a practice block they were instructed for the PM task. Subsequently, they were distracted by a filler-task lasting about 5 minutes (spatial reasoning subscale of the PMA; see corresponding section below). Afterwards they had to perform the OT with the embedded PM task, without having instructions repeated. Participants, who never responded to the PM cues, were asked control questions with increasing specificity, in order to evaluate whether their failure was a pure PM deficit or rather due to forgetting or misunderstanding instructions (Kvavilashvili et al., 2008): 1) “Was there something else to do besides putting the objects in the right rooms?” 2) “Was there something else to do whenever specific pictures appeared? 3) ”Was there something to do when the picture of a fruit appeared?” 4) ”Didn’t you have to press the spacebar whenever the picture of a fruit appeared?” (see also Cottini et al., 2018). Children who were not able to answer the last question were excluded from analyses, because their failure was likely to be due to forgetting or misinterpretation of PM instructions (Kavilashvili et al., 2008).

Procedural Metamemory

Performance predictions. To evaluate children’s procedural MM in relation to PM, we asked children to predict their PM performance (see Kvavilashvili & Ford, 2014). To investigate the effect of making explicit predictions of the future performance on performance itself, we split our sample into two groups (Cottini, Basso, & Palladino, 2018; Meier et al., 2011; Rummel et al., 2013). Consequently, only half of the children were asked to make performance predictions after being instructed on the PM task. For those children, the following questions were shown on the screen and read aloud by the experimenter: “Will you remember to press the spacebar whenever a fruit appears on the screen?” After responding with either “Yes, I will remember” or with “No, I will forget”, the children were asked to indicate their prediction confidence: “How sure are you that you will remember/forget?” Confidence judgments had to be indicated on a 3-point Likert scale (key 1 = not sure, key 2 = sure, key 3 = very sure).

Retrieval experience. At the end of the PM task, children who remembered the PM task were asked to report whether they searched for the PM cues or whether intention retrieval was automatic (i.e., popping into mind when a cue was presented; Meier et al., 2011). One point was assigned for automatic retrieval; two points were assigned when they reported both (e.g., "I did not search for it at the beginning but later I did"); and three points were given for strategic search of the PM cues (e.g., "I repeated fruit in my mind and searched for it during the task").

Declarative Metamemory

A modified version of the *story task* "The Captive Princess" (Cornoldi et al., 1991; Cottini et al., 2018) was used to investigate children's declarative MM. The tale is about a princess closed in a castle because of witchcraft, and a prince, who wants to save her. On his way to the castle, the prince runs into a farmer who reveals him that to break the spell he has to ask for help to a wise man living far away on the peak of a mountain. The farmer in return asks the prince to bring him a medicine from the wise man. After promising that to the farmer, the prince departs for his long trip. The first part ended with the wise man revealing the antidote (a sequence of actions) to the prince.

This part included three questions: one evaluating *PM* ("Is there something else the prince has to remember to do?") and two evaluating *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?"). Subsequently, the story continued with the prince riding back to the castle. This second part ended with the prince arriving to the castle's gate and consisted of four questions: two assessing 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 evaluating *knowledge of retrieval* ("What can the prince do in order to recall the antidote?"). The final part of the story is about the prince riding back to the old man to ask him the antidote and the medicine for the farmer. This third part consisted of two questions assessing *knowledge of storage*, that is, participant's insight into memory maintenance strategies (i.e., "What can the prince do to be sure to remember to ask for the medicine this time?" and "What can the prince do to be sure to recall the antidote once he arrives in front of the castle?").

Children's responses to the various questions were encoded according to the authors

(Cornoldi et al, 1991): The questions relative to *knowledge of forgetting* were assessed on a 7-point Likert scale (e.g., 0 = "I don't know"; 7 = "The prince may has forgotten because too much time has passed, during which he had to remember too many things"). The purpose of this scale was to assess children's knowledge regarding the decay of information from memory, and the various factors influencing memory during the time delay between encoding and retrieval. *Knowledge of retrieval* was rated on a 5-point Likert scale (e.g., 0 = "I don't know"; 5 = "He has to recover information he used when he learned from the sage what to do"). This scale was aimed at evaluating children's knowledge regarding rehearsal processes as well as mental activities able to prevent the decay of information from memory. Finally, *knowledge of storage* was rated on a 3-point Likert scale (e.g., 1 = magic retrieval or simply paying attention; 3 = rehearse information in the head). Cronbach's alpha (α) was calculated, revealing a good internal consistency, $\alpha = .61$.

Verbal and non-verbal abilities

Verbal meaning sub-scale: Primary Mental Abilities. Children's vocabulary knowledge was evaluated using the PMA verbal meaning subscale (Thurstone & Thurstone, 1981). The paper-pencil task consisted of a total of 30 items and required for each to choose one picture out of four on the bases of the given instructions (e.g., "Mark the apple"). For each correct answer one point was assigned.

Spatial reasoning sub-scale: Primary Mental Abilities. Children's non-verbal abilities were evaluated using the PMA spatial reasoning sub-scale (Thurstone & Thurstone, 1981). The paper-pencil task consisted of a total of 27 incomplete geometrical figures which had to be completed by selecting one of four possible alternatives. For each correct answer one point was assigned.

Verbal working memory

Digit span forward. The passive storage of verbal WM was assessed by means of the forward digit span task. The experimenter presented orally a series of digit-lists with an increasing number of items (starting from three). Digits were presented one per second, and at the end of each list participants had to repeat them in the same presentation order. Three trials were presented for each digit-length. If at least two of three were repeated correctly, the subsequent digit-list was increased of one unit; otherwise the task was stopped. There was no time limit to recall the digits. The length of the last properly recalled list was considered as the final score.

Digit span backward. The active storage of verbal WM was assessed using the backward digit span. Again the experimenter presented orally a series of digit-lists, but this time the participants were required to recall them in the inverted order. Procedure and scoring method was similar to the "digit span forward" (see section above).

Inhibitory control

A computerized version of the Go-No/Go task was used to assess children's ability to inhibit prepotent responses (see Brocki & Bohlin, 2004). The task was run with the SuperLab Software. It consisted of a total of 50 Go- and No/Go-stimuli (yellow and blue sphere, respectively) which were presented one by one on a black background (500 ms). In order to induce a habitual response, the majority of the trials were Go-stimuli (75%). Every stimulus was anticipated by a fixation cross (250 ms) and followed by a randomly variable inter-stimulus interval ranging from 2,550 ms to 2,783 ms. Participants were required to respond as fast as possible by pressing the spacebar whenever a Go-stimulus appeared, whereas they had to inhibit their response whenever a No-Go stimulus was presented. For scoring we considered the number of commission errors (i.e., pressing the spacebar to a No-Go stimulus) and omission errors (i.e., not responding to a Go stimulus). Commission errors represent a direct measurement of inhibitory control, whereas omission errors are considered a measure for inattention.

7.3. Results

7.3.1. Descriptive statistics

Children's mean scores (and standard deviations) on the various cognitive tests divided for the two groups (with vs. without predictions) at Time 1 and Time 2 are summarized in Table 10. The comparison between the non-prediction and prediction group was performed by means of a Multivariate Analysis of variance. In both evaluation times, the two groups had equal cognitive abilities, $F(10, 43) = 0.692$, $p = .726$, $\eta^2_p = .14$. In Time 1, children in the two groups had equivalent performance on all measures: verbal abilities, $p = .266$, $\eta^2_p = .02$; inhibitory control, $p = .832$, $\eta^2_p = .001$; WM digit span forward, $p = .266$, $\eta^2_p = .02$; WM digit span backward, $p = .65$, $\eta^2_p = .004$; declarative MM, $p = .83$, $\eta^2_p = .001$. Similarly, in Time 2, children's data were equivalent, showing that the two groups did not differ in any of the variables: verbal abilities, $p = .153$, $\eta^2_p = .04$; inhibitory control, $p = .47$, $\eta^2_p = .01$; WM digit span forward, $p = .73$, $\eta^2_p = .002$; WM digit span backward, $p = .97$, $\eta^2_p < .01$; declarative MM, $p = .66$, $\eta^2_p = .004$.

Table 10

Means (and standard deviations) of raw scores at the various tests at Time 1 and Time 2.

	Time 1		**Time 2**		
Variables	**No predictions** (*n* = 30)	**Predictions** (*n* = 29)	**No predictions** (*n* = 30)	**Predictions** (*n* = 29)	**Actual range**
PMA verbal abilities	25.93 (1.96)	25.31 (2.09)	27.14 (3.09)	25.62 (4.57)	0–30
Digit Span forward	4.43 (0.79)	4.19 (0.75)	4.54 (0.84)	4.62 (0.85)	-
Digit Span backward	2.86 (0.71)	2.7 (0.71)	3.11 (0.83)	3.12 (0.71)	-
Inhibitory control	1.36 (1.10)	1.42 (1.17)	1.36 (1.16)	1.65 (1.77)	-
Declarative MM total	12.96 (3.55)	12.77 (3.06)	15.96 (2.86)	16.27 (2.09)	0–22

Note. The number of females in the non-prediction group was 17, and in the prediction group 16. PMA, Primary Mental Abilities; for inhibitory control the mean number of errors has been considered.

Developmental changes in the various cognitive measures are displayed in Table 11. Children's performance were relatively stable and improved significantly nearly in every measure from Time 1 to Time 2: verbal ability, $r(54) = .32$, $p = .02$; WM digit span forward, $r(57) = .56$, $p < .001$; WM digit span backward, $r(56) = .37$, $p = .005$; inhibitory control, $r(59) = .37$, $p = .004$; and declarative MM, $r(59) = .43$, $p = .001$.

Table 11

Contrast between means (and standard deviations) at Time 1 and Time 2 for the various measures included in this study.

Variables	**Time 1**	**Time 2**	*t*	df	*p*	95% CI		Cohen's
						LL	*UL*	*d*
Verbal ability	25.63 (2.03)	26.41 (3.92)	−1.51	53	.137	−1.81	0.26	0.25
Digit Span forward	4.28 (0.77)	4.53 (0.85)	−2.43	56	.018	−0.45	−0.04	0.31
Digit Span backward	2.79 (0.70)	3.09 (0.76)	−2.74	56	.008	−0.52	−0.08	0.41
Inhibitory control	1.46 (1.13)	1.56 (1.74)	−0.53	58	.600	−0.49	0.29	0.08
Declarative MM	12.66 (3.30)	15.83 (2.69)	−7.54	58	<.001	−4.01	−2.33	1.05

7.3.2. Procedural metamemory and prospective memory performance

Performance predictions. Out of the 59 children, two were excluded from analysis because at Time 1 they failed to remember PM task instructions. Thus, their performance was not related to PM difficulties but rather to RM or comprehension difficulties (Kvavilashvili et al., 2008). The final sample consisted of 57 children, of which 29 received standard instructions and 28 had to predict their PM performance (see Table 12). Within this group, at Time 1, all the children predicted to remember the PM task, being 13 (46%) “sure” and 15 (54%) “very sure” of their prediction. Of the 13 children who were sure of their prediction, 8 remembered the PM task and 5 did not, whereas of the 15 children who were very sure of their prediction, 12 remembered the PM task and 3 did not. Chi-square analysis showed that confidence judgments were not related to actual performance, X^2 (1, $N = 28$) = 1.163, $p = .281$ (phi coefficient = .204). At Time 2, again all the participants predicted to remember the PM task, of which 16 (57%) were “sure” and 12 (43%) “very sure” of the own prediction. Of these 28 children, 24 (86%) correctly remembered the PM task, suggesting that children were able to predict their actual performance with reasonable accuracy. Of the 16 children who were sure of their prediction, 14 remembered the PM task and 2 did not, whereas of the 12 children who were very sure of their prediction, 10 remembered the PM task and 2 did not. Chi-square analysis showed that confidence judgments were not related to actual performance, X^2 (1, *N* = 28) = 0.97, *p* = .755 (phi coefficient = –.059), indicating that children's confidence judgments were not related to the number of PM hits.

Table 12

Confidence judgments of performance predictions related to the number of remembered cues in the PM task at Time 1 and 2.

			Remembered			
	Prediction Confidence	***N***	**0**	**1**	**2**	**3**
Time 1	Sure	12	5	1	3	4
	Very sure	15	3	2	4	6
Time 2	Sure	16	2	2	4	8
	Very sure	11	2	0	4	6

Retrieval experience. Frequencies of retrieval experience and PM hits in Time 1 and Time 2 are reported in Table 13. Out of the 28 children who remembered to perform the PM task at Time 1, 7 children (25%) said that the PM cues popped into their mind, 19 (68%) searched for them, and 2 (7%) reported that the first PM cue popped into their mind and subsequently they searched for the remaining cues. Chi-square analysis showed that retrieval experience was not significantly related to the number of PM hits, X^2 (4, *N* = 28) = 6.47, *p* = .17 (phi coefficient = .48). At Time 2, 50 children remembered the PM task, of which 13 (26%) reported a spontaneous retrieval, 27 (54%) a search experience, and 10 (20%) a combination of the two. Chi-square analysis revealed that the relation between retrieval experience and PM performance did not reached the significance threshold, X^2 (4, *N* = 50) = 8.47, *p* = .07 (phi coefficient = .41). Finally, making predictions did not influence retrieval experience neither at Time 1, X^2 (2, N = 28) = 2.14, p = .34 (phi coefficient = .28), nor at Time 2, X^2 (2, N = 51) = 2.00, p = .91 (phi coefficient = .06). However, at Time 1 confidence judgments were positively related to retrieval experience, X^2 (2, N = 20) = 7.15, p = .03 (phi coefficient = .60). Children who were "very sure" (60%) mainly reported a search experience (75%), whereas those being only "sure" (40%), mainly reported a spontaneous retrieval (62.5%). At Time 2, of the 10 children who were "very sure" (40%), 7 (70%) reported a search experience, whereas of the 15 children (60%) who were "sure", 7 (46.7%) reported a spontaneous retrieval, 5 (33.3%) a search experience, and 3 (20%) a combination of the two. Although the frequencies seem to confirm the pattern of Time 1, the relation between confidence judgments and retrieval experience at Time 2 did not reach the significance threshold, X^2 (2, N = 25) = 4.20, p = .12 (phi coefficient = .41).

Table 13

Reported retrieval experience related to prospective memory hits.

			Remembered		
	Retrieval experience	***N***	**1**	**2**	**3**
Time 1	Automatic	7	2	3	2
	Automatic + search	2	1	1	0
	Search	19	1	6	12
Time 2	Automatic	13	1	5	7
	Automatic + search	10	3	3	4
	Search	27	1	5	21

7.3.3. Effects of performance predictions on ongoing task and prospective memory performance across time

Ongoing task performance. Mixed analyses of variance (ANOVA) with the between-subjects factor group, and the within-subjects factor time were performed on OT accuracy rates and RTs separately. OT accuracy rates remained similar across time and between groups (see Figure 7a).

Results showed that neither the effect of group, nor the effect of time, nor their interaction were significant, $F(1, 55) = 0.483$, $p = .49$, $\eta^2_p = .009$, $F(1, 55) = 0.026$, $p = .873$, $\eta^2_p < .001$, $F(1, 55) = 0.553$, $p = .46$, $\eta^2_p = .01$, respectively. RTs for the OT changed over time and differed between the two groups (see Figure 7b). Results showed that the effects of time and of the Time × Group interaction were significant, $F(1, 55) = 4.385$, $p = .04$, $\eta^2_p = .07$, $F(1, 55) = 5.984$, $p = .02$, $\eta^2_p = .10$, respectively. The effect of group was not significant, $F(1, 55) = 1.730$, $p = .19$, $\eta^2_p = .03$. Post-hoc comparisons on the Time × Group interaction showed that in Time 1 children in the prediction group had slower RTs than those in the non-prediction group, $p = .02$, $\eta^2_p = .10$, whereas OT RTs in Time 2 did not differ between groups, $p = .98$, $\eta^2_p < .001$.

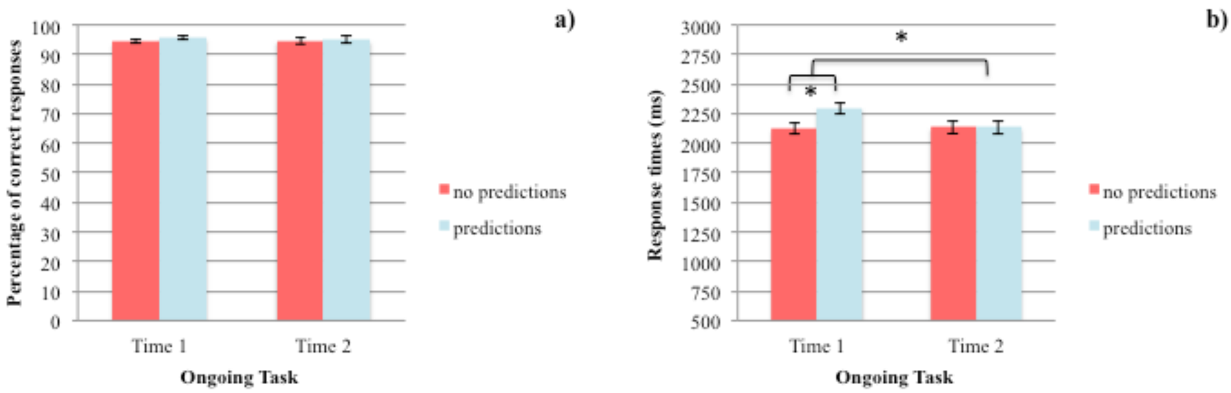

Fig. 7. Percentage of correct responses **(a)** and RTs **(b)** to the ongoing task for the prediction and the non-prediction group at Time 1 and Time 2. Error bars represent standard errors.

Prospective memory performance. Mixed ANOVAs were performed on PM accuracy and RTs separately with the between-subjects factor group, and the within-subjects factor time. PM accuracy changed over time and across groups (see Figure 8a). Results showed that the effects of time and of Time × Group interaction were significant, $F(1, 55) = 43.706$, $p < .001$, $\eta^2_p = .443$, and $F(1, 55) = 14.145$, $p = .001$, $\eta^2_p = .21$, respectively. The effect of group was not significant, $F(1, 55) = 2.781$, $p = .10$, $\eta^2_p = .05$. The post-hoc comparison of the Time × Group interaction showed that accuracy at Time 1 was significantly higher in the prediction group compared to the non-prediction group (p = .002, η^2_p = .16), whereas at Time 2 there were no group differences (p = .46, η^2_p = .01).

RTs on PM targets were similar for the two groups, but changed from Time 1 to Time 2 (see Figure 8b). Analyses revealed that the effect of time was significant, $F(1, 25) = 21.050$, $p < .001$, η^2_p = .46, whereas both the effect of group and their interaction were not, $F(1, 25) = 0.09$, p = .77, η^2_p = .004, $F(1, 25) = 1.531$, p = .228, η^2_p = .06, respectively.

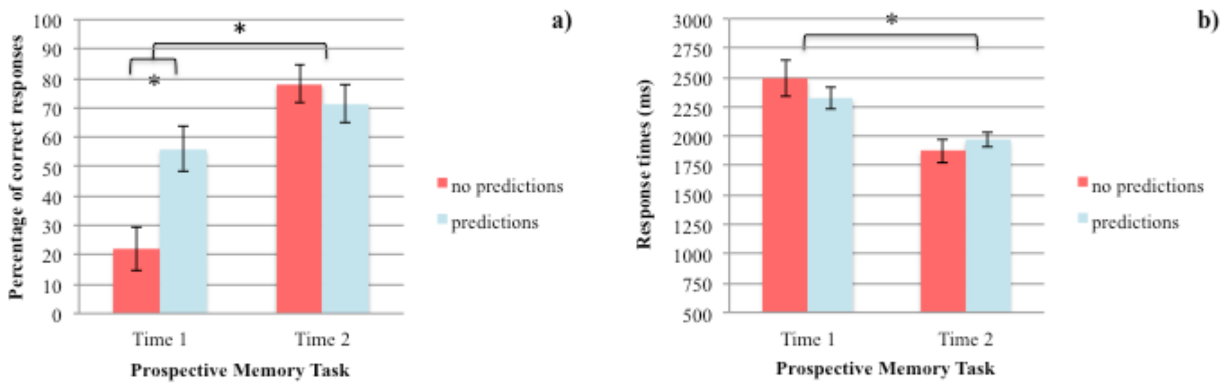

Fig. 8. Percentage of correct responses **(a)** and RTs **(b)** to the prospective memory task for the prediction and the non-prediction group at Time 1 and Time 2. Error bars represent standard errors.

7.3.4. Relations between prospective memory, metamemory and executive functions across time

First, we conducted exploratory correlation analyses to observe relations between PM and the other variables included in this study across time. At Time 1 PM accuracy was significantly related to predictions, $r(57) = .40$, $p < .01$, to inhibitory control, $r(57) = -.29$, p = .03 and declarative MM, $r(57) =.32$, p = .02, at Time 1. At Time 2 PM accuracy correlated only with PM accuracy obtained at Time 1, $r(57) = .32$, p = .02.

Subsequently, we performed a multiple linear regression analysis to explore variance in PM performance at Time 1. As predictor variables we included group (prediction, no prediction), inhibitory control and declarative MM using the Enter method. Results showed that the model was able to significantly explain outcome, $F(3, 53) = 9.176$, $p < .001$, with R^2 = .42. All three included factors were significant predictors of PM performance. Children in the prediction group, as well as those with high declarative MM scores and a low error rate on the Go/No-Go task, had a significantly higher PM performance: $\beta = .43$, $t = 3.83$, $p < .001$, for group; $\beta = .28$, $t = 2.47$, $p = .02$, for declarative MM; and $\beta = -.29$, $t = -2.54$, $p = .01$, for inhibitory control.

To examine possible predictors of developmental changes in PM performance between Time 1 and Time 2, we calculated the delta of PM accuracy at the two evaluation times. Since PM performance at Time 2 did not correlate with any other cognitive measure, with the exception of PM performance at Time 1, we included it as predictor variable. Moreover, we included the three predictor-variables which were related to PM accuracy at Time 1. The resulting regression model was significant, $F(4, 52) = 14.902$, $p < .001$, with $R^2 = .53$. Children who had a low PM performance at Time 1 were those who improved the most at Time 2. In fact, PM accuracy at Time 1 was the only variable which significantly predicted PM performance at Time 2, $\beta = -.64$, $t = -5.55$, $p < .001$.

7.4. Discussion

The purpose of the current investigation was to examine the longitudinal development of PM, MM and EFs in children between the age of 7 and 8 years. Procedural MM was evaluated by using the performance prediction paradigm prior to an event-based PM task. We were further interested in examining whether the prediction-effect on PM performance would persist across time. Thus, half of the sample was asked to predict PM performance, whereas the other half served as control group (see Cottini et al., 2018). Additionally, children were asked whether they searched for the PM targets or whether their retrieval was spontaneous (i.e., recognized when presented on the screen). Furthermore, we evaluated children’s declarative MM, inhibitory control, and WM abilities. The same tasks were administered at Time 1 and Time 2, with a mean delay of about 12 months between the two evaluation times.

Consistent with our hypothesis, children's performance in the PM task, the WM span forward and backward, as well as the declarative MM task improved considerably from Time 1 to Time 2. In contrast, children's performance did not change over time in inhibitory control and verbal abilities. At Time 1, children in the prediction group outperformed children in the control group. This prediction advantage occurred with slower OT RTs, indicating that children's strategic monitoring processes were boosted. Moreover, inhibitory control and declarative MM both significantly predicted PM performance at Time 1, confirming our hypothesis as well as previous studies on the role of inhibition (see Mahy, Moses et al., 2014a). However, group differences disappeared at Time 2, with PM and OT performance being comparable between the two groups. Almost all the children at Time 2 remembered to perform the PM task (89.5%) and their percentage of correct PM responses was quite high (*M* = 74.85; *SD* = 34.98). This may suggests that performance was close to the ceiling-level, indicating that the PM task used in this study might has been either not suitable to be administered a second time or too simple for 8-year-old children. This might explain the null-effect of performance predictions which have shown to improve PM performance only in resource demanding tasks (Cottini et al., 2018; Meier, et al., 2011; Rummel et al., 2013). Support for this assumption may be also the lack of correlations between PM performance at Time 2 and the measures of inhibitory control, WM and declarative MM. The only variable which significantly explained variations in PM performance at Time 2, was PM performance at Time 1. This suggests that children might have relied on their past experience of performing the task. In fact, especially those children who obtained a low score on the PM task at Time 1 (the majority of them was in the non-prediction group), showed a significant performance increase at Time 2. It is likely that their failure in the PM task at Time 1 influenced their motivation to succeed at Time 2.

As expected children in the prediction group were capable of predicting the tendency of their future PM performance, with 71% of the children making an accurate prediction at Time 1, and 86% at Time 2. On the other hand, children's confidence judgments were rather imprecise, being not related to the actual PM performance neither at Time 1 nor at Time 2. This supports one of our hypotheses according to which the performance prediction paradigm used in this study was not sensitive enough to measure children's procedural MM. In fact, again children's predictions were highly positive with all of them predicting that they would have remembered the PM task (for similar results see Cottini, Basso & Palladino, 2018; in preparation). This suggests that other factors might have influenced those judgments (see Schneider, 2015). However, an interesting outcome was that children's confidence judgments were related to retrieval experience, with children being very sure of their prediction also reporting more frequently a search experience. On the other hand, the relation between retrieval experience and PM performance was rather weak, indicating that children had little insight in their memory processes or that they could not translate their knowledge in efficient control. Consequently, they probably knew which strategy they could use to perform the task, but they had not enough cognitive resources to efficiently apply that strategy.

Although the present study revealed some interesting preliminary findings on the relation between MM and PM, there are some potential limitations which have to be discussed. First, we would like to address the problem resulting from the repeated evaluation of the same tasks within longitudinal studies. This has frequently shown to make it difficult to draw reliable conclusions and to interpret data on developmental improvements (see Grammer, Coffman, & Ornstein, 2013; see Spiess et al., 2016). For instance, familiarity and experience with the task demands or with the experimental situation are likely to influence performance when being faced with the same task a second time. As a consequence, this would probably facilitate participants' engagement in the task, influencing performance in some degree. We assumed that a 12 months delay would be enough to induce forgetting and to reduce children's task familiarity. However, the highly motivating PM task used in this study has probably influenced performance at Time 2 to a greater extent as expected. Thus, the PM task used in this study was not suitable to be administered a second time, thus, to be used to investigate longitudinal development.

Another related problem concerns methodology of developmental research designs. Studies comparing different age groups frequently face problems related to the adjustment of task difficulty and length for children in both cross-sectional and longitudinal designs (see Kvavilashvili, Kyle, & Messer, 2008). The task used in this study might have been too simple for 8-year-old children and may be not suitable to detect age-related improvements after the age of 7 years.

Future studies investigating the development of PM should consider these potential problems by designing appropriate experimental tasks able to avoid ceiling or floor effects as well as to reduce familiarity effects when examining development in longitudinal designs. Moreover, other methods for studying procedural MM should be included in future studies. As confirmed in the present investigation, performance predictions are not indicative for children's procedural MM being rather influenced by other factors (see Schneider, 2015). Consequently, postdictions (i.e., a posteriori performance judgments) might be better indicators of children's procedural MM. This has been frequently shown in RM studies and it would be interesting to track the development of this process in relation to PM. Moreover, the investigation of the age-related changes in the effective application of strategies on PM tasks should be further addressed in developmental research. This might increase our knowledge about the different processes besides EFs which are likely to support the development of PM in children.

8. General discussion

The overall aim of this dissertation was to investigate the role of procedural and declarative MM, as well as EFs in PM of 7- and 8-year-old children. Consequently, four research questions were proposed aiming at exploring the following: 1) the effect of performance predictions on children's subsequent PM performance; 2) children's ability to judge PM performance prior and subsequent to a PM task, as well as their strategy knowledge and their ability to use that strategies in an effective way; 3) the role of declarative MM and EFs in PM of school-aged children; 4) the longitudinal relationships between the development of PM, MM and EFs in children aged 7 and 8 years. In the following paragraph, the outcomes of the three experimental studies included in the present work will be summarized and discussed according to the four research questions. Subsequently, results will be integrated in a theoretical and methodological framework of PM development and, finally, directions for future research will be presented.

8.1. Discussion of Research Questions

8.1.1. Can performance predictions benefit children's prospective memory on a resource-demanding task?

Results of Study 1 revealed that "yes", making performance predictions can improve children's subsequent PM performance on a resource-demanding PM task. Indeed, children who had to predict future performance were more accurate and faster in the detection of categorical PM targets, compared to children receiving standard instructions. These results replicated previous studies with adults in which participants in the prediction group outperformed those in the control group (Meier et al., 2011; Rummel et al., 2013). Furthermore, the prediction-advantage in Study 1 occurred with slower OT RTs, indicating that children strategically monitored for the PM targets. This replicated Rummel and colleagues' study (2013) in which it was argued that performance predictions would reactively modify the processing of a PM task, changing attention allocation policies. However, the nature of this prediction-advantage is not completely clear since performance predictions in Study 1 as well as in Rummel and colleagues' study were not related to actual PM performance. Indeed, results of Study 1 showed that confidence judgments of predictions were not related to PM performance in the categorical task. On the other hand, they were related to OT RTs, with more cautious children being slower than overconfident ones. This suggests that children who were less confident about their predictions may have judged the task as being more difficult, which has in turn enhanced their engagement in strategic monitoring (cf. Rummel & Meiser, 2013). In this vein, a recent study with adults showed that the engagement in strategic monitoring could be affected by the manipulation of expectations about task demands (*ibidem)*. Although this would be a reasonable explanation, it necessitates further evidence.

Besides this, it has been argued that making performance predictions might has increased motivation and perceived importance of the prospective intention, resulting in enhanced monitoring. Manipulating the importance of a PM task has been frequently shown to improve PM performance by increasing the engagement in strategic monitoring (see Walter & Meier, 2014, for a review). Furthermore, similar to the prediction-manipulation it has been shown that the importance-manipulation affects PM performance in resource-demanding but not in more automatic PM tasks.

Study 1 showed for the first time that using performance predictions could benefit even children's PM performance by boosting strategic monitoring processes. Although the nature of this benefit is not yet completely clear and needs to be further investigated, performance predictions can be a valuable tool to increase our understanding of the cognitive strategies children use to perform different tasks.

8.1.2. How does procedural metamemory relate to children's prospective memory?

In all three experimental studies, children were able to predict the direction of their future outcome but when considering confidence judgments, these were rarely related to subsequent PM performance. Previous studies adopting the performance prediction paradigm in relation to RM have frequently found inconsistent results (see Schneider, 2015), and this was similar also in studies investigating adult's predictions for PM performance (e.g., Meeks et al., 2007; Rummel et al., 2013; Schnitzspahn et al., 2011). In contrast, 5-year-old children in Kvavilashvili & Ford's study (2014) were highly accurate in their performance predictions for a simple PM task. Some RM researchers claimed that accuracy of performance predictions might be influenced by various factors, such as motivation, task familiarity and experience, as well as assessment mode or training (see Schneider, 2015). Consequently, performance predictions are not necessarily indicative of MM deficits. For instance, performance predictions were frequently found to be inconsistent when tasks were unfamiliar. Moreover, performance predictions have been related rather to motivational factors such as wishful thinking rather than to MM (Schneider, 1998). Indeed, in all three experiments of the present work, the majority of the children predicted to remember the future task, suggesting that their predictions were probably related to high motivation rather than to their MM knowledge. Consequently, performance predictions may not be suitable to measure pure MM processes.

For this reason, a postdiction paradigm has been adopted in Study 2. This has shown to be a more suitable measure for procedural MM (Schneider, 2015). Consistent with our hypothesis, postdictions were highly related to PM performance and, replicating findings of the RM literature, confidence judgments of postdictions were also highly accurate (e.g., Visé & Schneider, 2000). Thus, children's MM knowledge about their general PM performance resulted to be quite high. In contrast, children's MM knowledge about their specific performance (i.e., the number of remembered PM cues) was less accurate. While 40% of the children were able to report the exact number of the correctly remembered and identified PM cues, about 60% of the children overestimated their PM performance. This is relatively in line with RM research, showing that children at this age are quite accurate but that they tend to overestimate their past memory performance (see Schneider, 2015). On the other hand, adults tend to underestimate their RM performance. This has been also shown in the only study to date, examining PM postdictions in adults (Meeks et al., 2007).

Besides the relation between PM performance and MM judgments, this research question aimed also at examining children's strategy knowledge as well as their ability to effectively apply this knowledge to the PM task. Results of Study 2 revealed a strong relationship between the reported strategy and the actual PM performance. This indicated that children at this age were quite aware of which strategy they have used, showing that their insight in the own memory processes was well developed. Moreover, those children reporting the use of an active strategy were also relatively able to translate it in effective control of PM performance. Indeed, results have shown that those children could adequately use that strategy, obtaining higher PM scores than children reporting more passive strategies. The significant higher OT performance slowing in those children further confirmed this hypothesis. However, only 46% of the children used an active strategy (i.e., repeating or having in mind the PM cues and searching for them). Developmental research on RM has shown that being aware of using a strategy and being able to use it adequately on a task is a sign of a well-developed MM system (see Schneider, 2015). The development of this relation, between MM knowledge and effective cognitive control, has shown to emerge not before the age of 7 years and to improve only later in childhood (e.g., Lockl & Schneider, 2003). Study 2 suggests a similar developmental trajectory for PM. Nevertheless, future studies are needed to evaluate this hypothesis by comparing different age groups.

In sum, results have shown that procedural MM is related and plays an important part in children's PM. To our knowledge this is the first study investigating different aspects of procedural MM in children's PM, and it is definitely worth continuing research in this realm aiming at increasing the understanding of the processes involved in PM.

8.1.3. How do executive functions and declarative metamemory relate to children's prospective memory?

Consistent with Mahy and colleagues' Executive Framework of PM development (2014a), the outcomes of the three experiments of the present dissertation revealed the significant contribution of inhibitory control, WM and set shifting in children's PM ability. Specifically, inhibitory control (Study 1) and set shifting (Study 2) have shown to relate to the ability to disengage from the OT and to respond to the PM cues, whereas WM and inhibitory control were related to PM performance (Study 1 and Study 3). These outcomes are in line with previous studies investigating the role of EFs in children's PM (e.g., Yang et al., 2011). However, it is important to say that in the experiments of the present dissertation as well as in previous research, the involvement of EFs has shown to be dependent on the nature of the PM task (see Mahy, Moses et al., 2014a). In fact, as claimed by the Executive Framework, the contribution of EFs to PM performance emerged mainly when task demands were high, whereas they were less important when the task was less demanding (Study 3, Time 2). Besides EFs, declarative MM resulted to be a significant predictor of PM performance. Knowledge about MM processes resulted to support PM performance, especially when the task was resource-demanding (Study 1 and 3, in the categorical PM task). Moreover, declarative MM has shown to be related to the engagement in monitoring processes needed for the successful execution of resource-demanding PM task.

For the first time, the present results have shown that besides EFs, declarative MM plays also an important role in children's PM. Although, further studies are needed to corroborate these findings, results of the present work suggested that MM should be definitely considered within the theoretical frameworks of PM development.

8.1.4. How does prospective memory develop between 7 and 8 years of age, and how does this development relate to metamemory and executive functions?

Study 3 has shown that PM performance improved considerably from 7 to 8 years of age. This replicated findings of both cross-sectional and longitudinal studies examining PM development during this age period (Yang et al., 2011; Smith et al., 2010; Spiess et al., 2016). Similar to previous studies, declarative MM (e.g., Fritz et al., 2010) as well as EFs (e.g., Diamond, 2013) improved significantly over this time period. However, Study 3 failed to answer the second part of the current research question. PM advances at Time 2 were not related to inhibitory control and declarative MM at Time 1. The PM task at Time 2 might have been too simple, since performance was close to the ceiling level. Developmental studies have often shown to face problems related to both floor- and ceiling-effects (see Kvavilashvili et al., 2008). Moreover, the only significant predictor of PM advances at Time 2 was PM performance at Time 1, suggesting that past experience with the PM task might has influenced performance at Time 2. Indeed, particularly children who had a low PM performance at Time 1, showed a greater performance increase at Time 2. PM failure at Time 1 might has strengthened children's memory for that task and subsequently enhanced motivation to succeed at Time 2.

Although lacking to respond to the present research question, Study 3 highlighted the potential problems emerging when studying PM development, especially when using longitudinal designs. Particularly within PM paradigms, performance is highly dependent on instructions and experience with the task. Thus, it would be important for future research to consider and reduce these potential confounds.

8.2. Theoretical and Methodological Implications and Future Directions: The Importance of Studying Metamemory in Prospective Memory Development

The primary aim of the present dissertation was to investigate the role of procedural and declarative MM in PM of school-aged children. A further aim was to study the relation between EFs and PM basing on the Executive Framework proposed by Mahy and colleagues (2014a). From the results of the three experimental studies, two key questions emerged which will be addressed in the next paragraphs: 1) How can procedural MM be studied in relation to children's PM; and 2) Why is it important to study MM in relation to children's PM.

8.2.1. How can procedural metamemory be studied in relation to prospective memory in children?

As seen in previous studies with adults as well as in the present work, performance predictions may not be considered as a pure measure of procedural MM (e.g., Rummel et al., 2013). Factors such as motivation, task familiarity and experience are likely to influence participant's predictions (Lockl & Schneider, 2003). Moreover, they can clearly contaminate PM performance itself (Rummel et al., 2013). Despite these caveats, assessing children's expectations can be helpful to better understand cognitive processes and strategies employed to perform a PM task. Consequently, future studies may evaluate children's expectations regarding task demands as well as their memory self-efficacy and motivation rather than asking to make general performance predictions. On the other hand, when using performance predictions it might be recommendable to use delayed predictions in order to give participants more information about the task. In fact, compared to immediate performance predictions, delayed performance predictions have shown to be more related to actual PM performance (Schnitzspahn et al., 2011). However, there is no evidence yet on whether delayed predictions would have a similar boosting effect on PM performance as has been shown with immediate performance predictions. Thus, it would be recommendable to include a control group whenever performance predictions, no matter if immediate or delayed, are included in a PM paradigm.

A clearly better and more suitable measure for the investigation of procedural MM in relation to PM has been shown by the postdiction-paradigm. This has been used only once in relation to PM, showing that judgments made after a PM task were highly related to adults' actual performance. The present examination has shown that postdictions can be used also to study this processes in children. Indeed, results have shown that even 7-year-olds can give appropriate evaluations about their own past PM performance. However, PM performance judgments are mainly descriptive and may give researchers little insight in the mechanisms underlying PM processes. On the other hand, questions about the used strategies have shown to be more informative about the cognitive processes engaged to successfully perform a PM task. The effect of strategies used to perform a PM task has never been studied before in children. The present work showed that children at this age have some insight into the own memory processes and that they were relatively abele to translate this knowledge in effective control of PM performance. Consequently, asking questions about the strategies used to perform a PM task might be a valuable method to increase our understanding of the cognitive processes underlying age-related differences in PM tasks. However, future studies are needed in which these processes are investigated in different age groups.

To sum up, for studying pure procedural MM knowledge, it would be more informative to use global and specific performance postdictions rather than performance predictions. On the other hand, if the aim would be to investigate the relation between MM knowledge and the ability to effectively control and regulate the own PM performance, using self-reports about strategy-use, asking to predict PM performance or to judge future task demands would be also useful methods.

8.2.2. Why is it important to study metamemory in relation to children's prospective memory?

MM has shown to play an important role in the development of RM (see Schneider, 2015). However, there are only few studies which have investigated MM in relation to children's PM, and there is any study to date examining these processes during child development. As the present experiments have shown, considering MM aspects in relation to PM performance can improve the understanding of the way cognitive resources are spent to successfully perform a PM task. Including MM measures when studying PM development can be a useful method to shed light on the complex interplay between MM knowledge, cognitive control and PM performance. Although there is little evidence yet, it is likely that these processes are intertwined and that their development is closely related and interdependent (see Mahy & Munakata, 2015). Importantly, studying these processes, their interrelation and their developmental trajectories would contribute to create a basis for research on interventions as well as to define the most important factors for the realization of educational programs.

8.3. Summary and Conclusions

In sum, the outcomes of the present dissertation have shown that children's performance on a resource-demanding PM task could benefit from making explicit performance predictions. This prediction-induced PM advantage has shown to be associated to an enhancement of strategic monitoring processes, functional to successfully perform that particular PM task. On the other hand, predictions did not affect performance on PM tasks which were less resource demanding or relying more on associative processes. Although performance predictions are commonly used to measure procedural MM, they have frequently shown to be influenced by other factors, which are different from MM. In fact, in our experiments, confidence judgments of predictions were rarely related to the subsequent PM performance. In contrast, children's postdictions of global performance were highly accurate, showing that children at this age had a good insight in the own PM ability. However, postdictions on the specific PM performance tended to be overestimated. Children's procedural MM has been further studied by investigating children's knowledge about the strategy used to perform the PM task as well as their ability to adequately adopt the reported strategies.

Results have shown that 7- and 8-year-old children had a relatively good insight in their own PM and that those children who reported the use of an active strategy were also relatively able to apply that strategy and effectively control their PM performance. However, only about half of the participants showed to have well-developed MM abilities, indicating that these processes are still developing at this age. Finally, PM, MM and EFs have shown to improve considerably between the age of 7 and 8 years. However, our results were not able to outline longitudinal relationships between the investigated processes. Thus, future studies are needed to shed light on the role of MM in the development of PM.

To conclude, these are the first studies investigating the role of MM in PM of school-aged children by using different methods. Results replicated in part those of previous studies, showing the robustness of the different outcomes. These studies clearly highlighted the importance of studying different MM aspects in relation to PM during childhood for both theoretical and methodological reasons as well as for the identification of critical factors useful for the realization of educational programs.

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